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EVALUATION OF

THERMAL HETWORK CORRECTION PROGRAM

using test temperature data



- T. Ishimoto
- L. C. Fink

JANUARY 1972

Prepared for NATIONAL AERONAUTICS AND SPACE ADMINISTRATION Manned Spacecraft Center Houston, Texas

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Prepared for:

National Aeronautics and Space Administration Manned Spacecraft Center Under Contract NASA 9-10435

Prepared by:

Approved by:

J. 11 Bevans, Manager Heat Transfer & Thermodynamics Dept.

R. L. Dotts, NASA Technical Monitor NASA Manned Spacecraft Center

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SUMMARY

In a previous development a computer tool for correcting a thermal network (large and small) was generated. 1,2* As part of that study the computer tool was evaluated by using computer-generated temperatures which simulated perfect test temperature data. 3 The results were sufficiently encouraging to continue the evaluation process with test temperature data; as a result, an exploratory evaluation using test temperatures was pursued.

Two heavily instrumented platforms with and without a heat pipe from a previous study 4 and math-models generated using normal engineering techniques were employed. Evaluation of the two correction subroutines, one for large networks and one for small networks explored many of those factors considered to influence the correction process.

From a general assessment standpoint, the evaluation study revealed that small models with complete temperature measurements and without complete temperature measurements can be corrected with surprisingly good results. Larger models could not be corrected as well as the small models because of the need to utilize a particular correction subroutine developed to accommodate large models; although large model correction was not as accurate as desired, information on the functional-form inaccuracy was displayed.

It thus appears at this stage of the correction program evaluation that correction of small models is accurate and practical from a user input standpoint; a wide range of applications for small correction is apparent. Correction of larger models, although not entirely satisfactory from an accuracy standpoint, yields information on math-models that is not apparent by the normal inspection procedure.

^{*} Superscript numbers refer to literature listed in the Reference Section.

1.0 INTRODUCTION

Development of a thermal network correction program has evolved from concept through a feasibility study, through a computer program development procedure. The evaluation process examined a relatively small model (about 50 nodes) and a large model (about 500 nodes) using computer-generated temperature data with some measure of success. Use of experimental temperature data represents the next step in the evaluation procedure since other considerations not present with computer-generated information must be examined. These factors include inaccuracies of temperatures, insufficient number of temperature data points over a specified time period, lack of one-to-one correlation between temperature sensor and nodal locations, incomplete temperature measurements, and conversion of test data to the input format of the thermal network correction program.

The intent of this study was the evaluation of the thermal network correction program with the use of small thermal math-models with experimental temperature data. The math-models chosen for this evaluation study were those that described a physical system composed of both a conventional and a heat pipe platform. In the sections to follow a description of the models used, the results of the evaluation of the thermal network correction with experimental test data and input instructions for the thermal network correction program are presented.

2.0 THERMAL NETWORK CORRECTION EVALUATION WITH THE USE OF TEST DATA

Evaluation of the thermal network correction program with test data requires the examination of many factors, many of which are not present with the use of computer-generated simulated test data. These factors include condition of incomplete temperature measurements, lack of one-to-one correlation between temperature and nodal locations, timewise insufficiency of temperature data points and effects of different environmental conditions.

Another important evaluation consideration is the input requirements to the correction program. Because of the need to have flexibility, input requirements, and thus user input, can be expected to be rather difficult.

In this present evaluation study only a few of those factors that may influence the thermal network correction solution have been examined. A complete examination would be rather prohibitive. The system that was studied consisted of two platforms, one a conventional platform and the other a heat pipe platform. Both platforms were heavily instrumented and tested for several different environmental conditions. A description of the system is found in Appendix A.

A 34-node math-model of the conventional platform and a 41-node math-model of the heat pipe platform were generated as described in Appendix A with intent to study both platforms in detail. However, the similarity of both platforms negated the need to examine both platforms. The rather lengthy computer run-time with the 34-node model of the conventional platform with subroutine KALFIL, which solves the governing equations simultaneously, also necessitated the use of a reduced model of the conventional platform. A reduced model of 10-nodes without compromising the evaluation was generated and employed; this reduced model permitted the examination of more factors that could not be done with the larger models.

Test data used in the evalution were selected from a number of options that were available. The selected data are discussed and tabulated in Appendix B for each of the math-models.

In the paragraphs to follow, description of the studied conditions, model characteristics and evaluation results are presented.

2.1 Selection of Test Data and Interpolation

2.1.1 Test Data

From the numerous test conditions and data available on the platform system as described in Appendix B, a cool-down period without heat generation and a heat-up period were selected. The selected time periods and data are tabulated in Appendix B for both the 34-node conventional and 41-node heat pipe platforms. The averaged-data for the 10-node model of the conventional platform are also tabulated in Appendix B.

2.1.2 Interpolation

Since the time-wise spread between data points was much larger than the network computational time-increment, it was necessary to obtain more data points. This could be accomplished by manual interpolation or by employing a computerized scheme. The latter approach was used by employing a SINDA least squares subroutine coupled with special subroutines for "reading" and "expanding" the temperature data. A description of the test data interpolation and translation to the input format for the correction program is found in Appendix B.

2.2 Math-Models

2.2.1 34-Node Conventional and 41-Node Heat Pipe Platform Models

A 34-node math-model of the conventional platform reflecting the location and number of temperature measurements was generated; a 41-node math-model of the heat pipe platform was also similarly generated. No attempt was made to accurately correlate by manual means uncorrected model and test temperature. Characteristics of these models are described in Appendix A. Most of the parameter correction results for these two models were obtained with subroutine KALØBS which operates on the nodes singly. Some results were obtained with subroutine KALFIL which operates on all the nodes simultaneously, but because of rather lengthly computer run-time, use of KALFIL was limited.

2.2.2 10-Node Conventional Platform Models

In order to exercise the capabilities of KALFIL more fully with reasonable run times, a 10-node model of the conventional platform was generated and utilized quite heavily, especially with subroutine KALFIL. Characteristics of the 10-node model are described in Appendix A.

2.3.1 <u>Subroutine KALØBS - Equation and Time-Wise Sequential</u> Unbounded All Soft Conductances (86) - Nodal Arrangements

The correction capability and limitations of subroutine KALØBS were explored by considering all (86) of the conductances to be soft. Test data during the cool-down period were used. Initially the soft parameters were For the nodal arrangement (numerical order) specified to be unbounded. tabulated in Table A-la, the correction behavior of several soft conductances (among 86) in terms of time-slices of data is tabulated in Table 2-1. Note that many of the soft parameters have become negative. The correction of these soft conductances was re-examined by changing the nodal arrangement to the one tabulated in Table A-1. This arrangement permits the correction of the more important parameters at the beginning of the correction process. Conductance correction results are tabulated in Table 2-2. Note that a few negative conductances remain. Evaluation of the sensitivity coefficients generated by the use of subroutine STEP reveals that many of the negatively corrected soft parameters, such as conductors 58 and 71, have relatively low sensitivity coefficient values. In general, parameters with low sensitivity are difficult to correct accurately.

In order to obtain an indication on the parameter correction accuracy, the corrected soft parameters were used to generate steady temperatures for those environmental conditions corresponding to test temperatures at time-slice one (refer to Appendix C). The steady state temperatures for the uncorrected model and the two corrected model cases (negative conductances were set to a small positive value) are tabulated in Table 2-3. These results show that the parameter correction accuracy was not accurate since the analytical and test temperatures did not correlate well. The results do show, however, the importance of nodal arrangement when using subroutine KALØBS since one nodal arrangement yielded much better results than the other. The results also indicate that the correction of a large number of parameters is difficult and may not be accurate with KALØBS. The

Table 2-1. Correction Behavior of Several Conductances Among 85 Soft Conductances, 34-Node Conventional Platform, Unbounded Corrections, KALØBS Cool-Down Condition, Nodal Input Order: 1,2,3,...,48

							Time-Slices* •				-
Conductor #	Description	Original Value Btu/hr °F	t = 0 hr	2	3	. 5	10	20	30	40	50 t = .24 hr
1	<u> </u>	.657	.657	.663	.664	.668	.716	.983	1.26	1.34	1.34
5	Ť	.657	.657	.687	.611	.341	.022	,041	.017	088	089
10		.009	.009	.009	.009	.010	.009	.009	.009	.009	.010
15	i	.551	.551	.551	,550	.547	.555	.674	.735	.672	.656
20	and	.212	.212	.202	.202	.203	.198	.192	.194	.196	.199
23	ا د	.219	.219	.220	.220	.219	.126	.215	.207	.209	.208
31	i en	.203	.206	.205	.202	.200	.223	.353	.458	.522	.593
35	fic	.170	.170	- 1.20	-1.20	107	553	.096	.063	.032	.049
40	Coefficient	.100	.100	.098	.094	.036	.070	.055	.053	.053	.056
. 45	ٽ	.297	.297	.299	.307	.322	.339	.350	.430	.499	.550
	r io	5.91	5.91	5.23	5.05	4.63	2.23	771	462	031	.857
2 51 4 54	อกค	9.28	9.28	3.26	3.17	3.13	3.13	3.00	2.83	2.47	1.03
53	Conduction	2.81	2.81	2.92	4.36	5,69	2.79	-5.25	-5.70 ·	-5.65	-6.10
53	Ĭ	1.69	1.69	-1.89	-1.86	-1.74	-1.97	-4.87	-6.20	-6.60	-6.73
71		75.0	75.0	4.59	2,39	.210	-1.38	-1.43	-1.82	-2.57	-2.30
7 1 74		37.5	37.5	37.8	31.3	30.7	14.0	9.71	3.56	.059	329
74 78	9	18.8	18.8	10.5	9.81	9.42	8.80	-4.85	-5.10	-3.52	-2.87
100	-	4.19 E-10	4.19 E-10	4.92 E-10	5.06 E-10	5.14 E-10	4.46 E-10	3.13 E-10	3.14 E-10	3.31 E-10	3.14 E-10
105	Δ	.298 "	.298 "	.304 "	.321 "	.385 "	.334 "	.154 "	.125 "	102 "	223 "
110		1.40 "	1.40 "	2.01 "	2.02 "	2.04 "	2.02 "	1.69 "	1.82 "	2.08 "	2.12 "
113	Coefficient Sink	2.40	2.40 "	3.19 "	3.20 "	3.05 "	2.50 "	2.40 "	1.87 "	1.60 "	1.52 "
120	icie	3.56 "	3.56 "	.076 "	697 "	921 "	642 "	.125 "	1.04 "	1.69 "	2.00 "
120	i k	1.19 "	1.19 "	-1.44 "	-2.44 "	-2.96 "	-3.00 "	-2.76 "	-2.61 "	-2.53 "	-2.49 "
	Sir	3.56	3.56 "	7.03 "	7.48 "	8.08 "	7.76 "	6.76 "	6.41 ".	6.34 "	6.29 *
122	Radiation	1.19 "	1.19 "	6.99 "	7.58 "	7.74 "	7,44 "	6.88 "	6.63 "	6.52 "	6.43 "
123	a ti	2.37 "	2.37 "	006 "	250 "	311 "	273 "	182 "	141 "	132 "	127 °
124	ibe	2.37 "	2.37	2.55 "	2.48 "	2.33 "	2.07 "	1.83 "	1.76 "	1.74 "	1.72 "
125		6.34 "	6.34 "	5.87 "	5.67 "	5.44 "	5.13 "	4,87 "	4.79 "	4.78 "	4.76 "
126 ·		4.75	4.75 "	3.14 "	2.49 "	2.06 "	1.80 "	1.67 "	1.61 "	1.58 "	1.55 *

^{*} Period between time-slice = .015 hr.

Table 2-2. Correction Behavior of Several Conductances Among 86 Soft Conductances, 34-Node Conventional Platform, Unbounded Corrections, KALBBS Cool-Down Condition, Nodal Input Order: 44, 43, 46,...,31,32

					·		- Time-Slices*				>
Conductor #	Description	Original Value Btu/hr °F	1 t = 0 hr	2	. 3	5	10	20 ·	30	40	50 t = .24 hr
1		.657	.657	.650	.650	.654	.703	1.00	1.29	1.32	1.34
5	Ĵ	.657	.657	1.45	1.55	1.56	1.21	.997	1.04	.974	.968
10		.009	.009	.010	.010	.009	.008	.006	.001	002	010
15	į	.551	.551	.551	.550	.548	.552	.363	447	573	946
20	į.	.212	.212	.197	.188	.128	012	035	010	.0006	024
23	- '	.219	.219	147	.146	.146	.143	.140	.137	.173	.210
31	Coefficient	.205	.206	.220	.231	.238	.223	.247	.318	:388	.482
35		.170	.170	.129	.114	.093	.059	.143	.261	.321	.348
40	Coe	.100	.100	.119	.138	.159	.174	.172	.171	.172	.175
45	uo	.297	.297	.507	.688	.834	.865	.860	.944	1.07	1.08
\sim	Conduction	5.91	5.91	6.71	6. 67	6.33	4.00	.008	1.08	1.28	1.77
51 54	npu	9.28	9.28	3.13	3.04	3.01	3.00	2.77	2.52	2.15	1.11
58	S.	2.81	2.81	10.2	10.4	11.1	16.4	18.5	15.4	12.6	11.4
62	. [1.69	1.69	-11.9	-11.7	-11.0	-11.9	-25.9	-33.6	-36.1	-37.5
71	e de la companya de l	75.0	75.0	6.53	4.86	4.35	5.79	7.24	7.31	7.16	7.13
74		37.5	37.5	64.4	-10.8	14.5	8.03	6.35	6.32	6.30	6.21
7 4 78	.	18.8	18.8	9.90	9.77	8.29	.212	6.57	10.6	7.65	6.71
100	- -	4.19 E-10	4.19 E-10	3.34 E-10	3.38 E-10	3.48 E-10	2.51 E-10	.565 E-10	.589 E-10	.699 E-10	1.02 E-10
105	A	.298 "	.298 "	.284 "	.281 "	.283 "	.290 "	.058 "	514 "	329 "	.118 "
110	į	1.40 "	1.40 "	1.74 "	1.75 "	1.77 "	1.72 "	.867 "	.645 "	.715 "	.711 "
113	Coefficient. Sink	2.40 "	2.40 "	3.23 "	3.23 "	3.10 "	2.63 "	2.57 "	1.98 "	1.68 "	1.59 "
120	ici	3.56 "	3.56 "	3.67 "	3.80 "	4.33 "	6.69 "	8.43 "	8.50 "	8.25 "	8.19 "
121	4. 7. 7.	1.19 "	1.19 "	1.26 "	1.28 "	1.36 "	1.69 "	. 1.80 "	1.80 "	1.83 "	1.87 "
122	Sir	3.56 "	3.56 "	3.43 "	1.76 "	3.05 "	8.96 "	9.81 "	9.77 "	9.77 "	9.71 "
123	to c	1.19 "	1.19 "	1.08 "	1.06 "	1.44 "	3.07 "	3.40 "	3.65 "	3.31 "	3.18 "
	att	2.37 "	2.37 "	2.33 "	2.13 "	1.46 "	-1.02 "	827 "	2.16 "	2.32 "	2.44 "
124	Radiation (2.37	2.37	3.02 "	15.7 "	13.6 "	12.1 "	10.9 "	10.9 "	10.9 "	10.8 "
125	. 1	6.34 "	6.34 "	6.40 "	6.38 "	6.33 "	6.31 "	5.66 "	4.27 "	4.42 "	4.30 "
126 127	·	4.75	4.75 "	4.55 "	4.55 "	4.52 "	4.39 "	3.96 "	3.37 "	2.85 "	2.56 "

^{*} Period between time-slice = .015 hr.

Table 2-3. Comparison of Test, Uncorrected and Corrected Conventional 34-Node Model, KALØBS Steady State Temperatures, 86 Soft Conductances, Cool-Down Period. 50 Time Slices*

Node		Uncorrec	ted Model	Corrected Model, 86 (All) Unbounded Parameters Nodal Order (Table A-la) Nodal Order (Table A-l) Applytical Difference Analytical Difference					
#	Test T _T (°F)	Analytical T _A (°F)	Difference (T _A -T _T)(°F)	Analytical T _A (°F)	Difference (T _A -T _T)(°F)	T _A (°F)	(T _A -T _T)(°F)		
	86.0	105.0	19.0	-45.6	-131.6	76.3	- 9.7		
	84.0	122.5	38.5	-45.2	-167.7	77.5	-6.5		
2	35.0	36.0	-1.0	-43.8	-78.8	17.8	-17.2		
3	10.0	-4.4	-14.4	-41.1	-51.1	12.1	-2.1		
4	116.0	131.4	15.4	-45.8	-161.8	101.3	-14.7		
5		254.8	15.8	-40.3	-259.3	184.3	-45.3		
6	229.0	132.5	16.5	-45.9	-161.9	100.4	-15.6		
7	116.0	203.2	27.2	-40.5	-216.5	153.5	-22.5		
. 8	176.0	. 64.0	12:0	-25.0	-91.0	42.3	-33.7		
9	76.0	9.4	-13.6	-27.2	-50.2	. 27.4	4.4		
10	23.0		33.7	-45.4	-136.4	128.3	37.3		
11	91.0	124.7 145.7	38.7	-42.0	-149.0	148.9	41.9		
12	107.0		10.2	-32.1	-74.1	33.8	-8.2		
13 .	42.0	55.2 . 9.3	-7.7	-30.8	-47.8	23.2	6.2		
14	17.0		17.0	-44.8	-133.8	78.6	-10.4		
21	89.0	106.0	28.0	-43.5	-136.5	72.2	-20.8		
22	93.0	121.0 37.0	-11.0	-43.1	-91.1	25.7	-22.3		
23	48.0		-18.7	-41.6	-56.6	19.6	4,6		
24	15.0	-3.7	23.5	-45.9	-157.9	119.2	7.2		
25	112.0	135.5	35.4	-41.4	-199.4	148.6	-9.4		
26	158.0	193.4	-3.6	-30.7	-95.1	42.8	-25.2		
27	68.0	64.4	-13.2	-28.1	-37.9	31.0	8.0		
28	23.0	3.6	22.7	-45.9	-172.6	119.8	15.8		
29	104.0	126.7		-30.6	-173.0	34.0	-86.0		
30	120.0	142.4	22.4	-30.6	-87.5	34.0	-25.0		
31	59.0	56.9	2.1	-29.2	-39.7	33.0	. 13.0		
32	20.0	10.5	-9.5	-58.6	-190.6	93.0	-12.0		
41	105.0	132.0	27.0	-58.6	-189.5	96.3	-12.7		
42	109.0	130.9	21.9	168.4	-36.2	153.8	-45.2		
43	189.0	204.6	15.6		95 .9	211.4	-34.6		
44	236.0	263.4	27.4	35913	-88.7	-60.0	-161.0		
45	101.0	63.7	-37.3	-25.0	118.3	39.9	-37.1		
4 6	77.0	64.4	-12.6	182.7	.8	91.8	42.8		
47	49.0	64.1	15.1	64.9		65.9	37.9		
48	28.0	9.4	-18.6	-6.0	-15.4	00.7			

^{*} Period between time-slices = .015 hour; Negative conductances set to a small positive value for corrected model steady state temperatures.

user should take particular care in identifying soft parameters and specifying the nodal order with the most important nodes ordered at the beginning.

Bounded All Soft Conductances (86)

In lieu of specifying the soft parameters to be unbounded, bounded corrections could also be specified. For an upper bound of +1.0* and a lower bound of $-(1.0 - .00001 \, \text{G}_0)$, the correction behavior is as shown in Table 2-4.

Bounded 16 Soft Conductances

Table 2-5 tabulates the correction behavior of 16 soft conductances with bounding of \pm .9 using subroutine KALØBS. Many of the conductances between the heater and the platform have bounded at the lower end. The corrected model steady state temperatures are tabulated in Table 2-6 along with test and uncorrected model temperatures. In general, the corrected model temperatures are much better than the uncorrected model temperatures.

2.3.2 Subroutine KALFIL - Equations Simultaneous and Time-Wise Sequential

An attempt was made to correct 86 soft parameters by using subroutine KALFIL, but the number of parameters which must also include all 34 temperatures was too large for obtaining a solution. As a result, a lesser number of soft parameters was required.

Bounded 16 Soft Conductances

Table 2-7 shows the correction behavior of 16 soft conductances with bounding of \pm .9 using subroutine KALFIL. These 16 soft conductances are the same as those studied using KALØBS. Eight are radiation conductors from the upper platform. Again using the temperatures at steady state conditions as basis for comparison, test, uncorrected and uncorrected model temperatures are tabulated in Table 2-6. In general, the corrected model temperatures are much better than the uncorrected model temperatures.

2.3.3 Comparison Between KALØBS and KALFIL and with Test Data

A comparison of KALØBS and KALFIL is given for the case of 16 soft conductances. This comparison is given in Table 2-7. Although the corrected model temperatures are better than the uncorrected model

^{* 1.0} means 100% bounding.

Table 2-4. Correction Behavior of Several Conductances Among 86 Soft Conductances, 34-Node Conventional Platform KALØBS, Bounding (+1.0, -(1.0 - .00001 G₀)), Cool-down Condition, Nodal Input Order: 44,43,46,...,31,32

						Т	ime-Slices*				
Conductor #	Description	Original Value Btu/hr °F	t = 0 hr	2	3	5	10	20	30	40	50 t = .24 hr
1		.657	.657	.653	.654	.657	.706	1.00	1.28	1.31	1.31
5		.657	.657	1.31	1.31	1.27	.7 E-5	.7 E-5	.7 E-5	.198	.316
10		.009	.009	.009	.009	.009	300.	.006	.002	.9 E-7	.9 E-7
15		.551	.551	.551	.550	.548	.582	.700	.309	.200	.6 E-5
20	•	.212	.212	.215	.222	.289	.424	.410	.297	.272	.348
23	•	.219	.219	.214	.215	.215	.212	.209	.205	.231	.257
31		.206	.206	.218	.227	.233	.223	.262	.337	.406	.412
35		.170	.170	.2 E-5	.2 E-5	.8 E-3	.026	.087	.103	.104	.105
40		.100	.100	.116	.132	.149	.160	.157	.155	.156	.159
45		.297	.297	.458	.594	.594	.594	.594	.594	.594	.594
		5.91	5.91	6.41	6.33	5.97	3.65	.514	.798	1.05	1,65
∾ 51 ∞ ₅₄	•	9.28	9.28	3.20	3.12	3.09	3.08	2.87	2.66	2.31	1.23
54 58		2.81	2.81	5.62	5.62	5.62	5.62	5.49	2.64	.532	.3 E-4
62	•	1.69	1.69	.2 E-4	.2 E-4	.2 E-4	.317	3.38	3.38	3.38	3.38
71		75.0	75.0	6.52	4.86	4.35	5.79	8.63	10.3	10.7	10.7
74		37.5	37.5	64.4	.4 E-3	: 2.74	1.82	1.67	1.72	1.71	1.71
74 78	•	18.8	18.8	9.90	9.77	9.29	.2 E-3	2.30	5.87	3.68	2.88
100		4.19 E-10	4.19 E-10	3.66 E-10	3.73 E-10	3.81 E-10	2.87 E-10	.966 E-10	.994 E-10	1.13 E-10	1.52 E-10
105		.298 "	.298 "	.278 "	.273 "	,273 "	.284 "	.087 "	.3 E-15	.299 "	.595 "
110		1.40 "	1.40 "	1.72 "	1.73 "	1.75 "	1.70 "	.737 "	.2 E-14	.1 E-14	.1 E-14
113		2.40	2.40 "	3.13 "	3.13 "	2.97	2.39 "	2.27 "	1.77E-10	1.51 E-10	1.44 E-10
120		3.56 "	3.56	3.67 "	3.80 "	4.33 "	6.69 "	7.13 "	7.13 "	7.13 "	7.13 "
		1.19 "	1.19 "	1.26 "	1.27 "	1.33 "	1.45 "	1.31 "	1.30 "	1.35 "	1.40 "
121		3.56 "	3.56 "	3.44 "	1.96 "	3.97 "	7.13 "	7.13 "	7.13 "	7.13 "	7.06 "
122		1.19 "	1.19 "	1.08 "	1.06 "	1.44 "	2.38 "	2.38 "	2.37 "	2.11 "	· 2.00 "
123		2.37	2.37 "	2.33 "	2.40 "	2.89 "	4.73 "	1.55 "	.2 E-14	.2 E-14	.2 E-14
124		2.37	2.37 "	3.02 "	4.74 "	4.50 "	4.28 "	4.19 "	4.23 E-10	4.23 E-10	4.24 E-10
125		6.34 "	6.34 "	6.40 "	6.38 "	6.33 "	6.31 "	5.66 "	4.28	4.42 "	4.30 "
126 127		4.75 "	4.75 "	4.55 "	4.57 "	4.67 "	5.60 "	9.50 "	9.50 "	9.50 "	9.50 *
											•

^{*} Period between time-slice = .015 hr.

Table 2-5. Correction Behavior of 16 Soft Conductances, 34-node Conventional Platform Correction Bounds ± .3, KAL@BS Cool-Down Condition, Nodal Input Order: 44,43,46...,31,32

	•						Time-sli	ces*			>
C	onductor #	Description	Original Value Btu/hr °F	1 t = 0 hr	2	3	6	9	12	15	t = .24 hr
	71		75.	75.	12.8	8.55	7.5 ✓		— Bounded ———		7.5
	. / ¹ . 72	7	75.	75.	32.7	28.9	29.0	28.7	25.4	22.8	22.2
	73		37.5	37.5	3.75			- Bounded			3.75
	73 74	Conductance .between heater- and platform	37.5	37.5	42.0	39.2	38.4	3.75		ed 	3.75
		ucta n he latí	100.	100.			Boun	ded			10.0
	75	Cond twee nd p	75.	75.	11.5	7.5		Bou	nded ———		7.5
	76	e pe			10.0	7.42	5.52	5.08	4.93	4.88	4.88
2-9	77	Ą	18.8	18.8		11.6	10.9	11.2	11.1	10.4	10.2
9.	78		18.8	18.8	12.6	11.0	1015				
	120	-	3.564 E-10	3.56 E-10	3.66 E-10	3.67 E-10	3.70 E-10	3.76 E-10	3.86 E-10	4.0 E-10	4.06 E-10
	121	Î	1.192 "	1.19 "	1.23 "	1.24 "	1.26 "	1.28 "	1.30 "	1.33 "	1.33 "
		ا چ د	3.564 "	3.56 "	3.45 "	3.42 "	3.53 "	4.68 "	6.35 "	6.77 "	6.77 "
	122	Radiation between heater and sink	1.192 "	1.19 "	1.12 "	1.09 "	1.09 "	1.16 "	1.32 "	1.51 "	1.56 "
	123	on b and	2.372 "	2.37	2.33 "	2.33 "	2.41 "	2.59 - "	2.77 "	2.87 "	2.87 "
	124	latio	u.572	2.37	2.48 "	3.15 "	3.81 "	3.65 "	3.40 "	3.14 "	3.06 "
	125	Rad		6.34 "	6.40 "	5.40 "	6.36 "	6.26 "	6.18 "	6.19 "	6.23 "
	126	·	0.342	6.34 4.75 "	4.59 "	4.58 "	4.57 "	4.59 "	4.63 "	4.63 "	4.70 "
	127	-	4.749 "	4./5	7.00	, ,					

^{*} Period between time-slice = .015 hr.

Table 2-6. Comparison of Test, Uncorrected and Corrected Conventional 34-Node Platform Model Steady State Temperatures 16 "Soft" Conductances Corrected with Transient Data, ± .9 Bound, KALFIL & KALOBS Cool-Down Condition, 17 Time-Slices* of Data

	,	Uncorrec	cted Model	KAL	FIL	KALØBS		
Node #	Test T _T (°F)	Analytical T _A (°F)	Difference (T _A -T _T)(°F)	Analytical T _A (°F)	Difference (T _A -T _T)(°F)	Analytical T _A (°F)	Difference (T _A -T _T)(°F)	
1 2 3 4 5 6 7 8 9 10 11 22 23 24 25 26 27 28 29 30 31 42 43 44 45 46 47 48	86.0 84.0 35.0 10.0 116.0 229.0 116.0 76.0 23.0 91.0 107.0 42.0 17.0 89.0 93.0 48.0 112.0 158.0 23.0 104.0 120.0 105.0 109.0 1	105.0 122.5 36.0 -4.4 131.4 254.8 132.5 203.2 64.0 9.4 124.7 145.7 55.2 9.3 106.0 121.0 37.0 -3.7 135.5 193.4 64.4 9.8 126.7 142.4 56.9 10.5 132.0 130.9 204.6 263.4 64.1 9.4	19.0 38.5 -1.0 -14.4 15.4 15.8 16.5 27.2 12.0 -13.6 33.7 38.7 10.2 -7.7 17.0 28.0 -11.0 -18.7 23.5 35.4 -3.6 -13.2 22.7 22.4 2.1 -9.5 27.0 21.9 15.6 27.4 -37.3 -12.6 15.1 -18.6	82.3 99.5 99.5 98.6 14.0 159.1 159.1 159.1 148.0 13.1 148.0 13.1 148.0 159.7 169.6 169.6 169.6 169.6 169.7 17.7	-3.7 15.0 -5.5 -12.9 -17.4 -14.9 -16.3 -16.5 -16.5 -17.6 -17.2 -17.5 -17.5 -17.5 -17.5 -17.6 -17.2 -11.5 -19.4 -9.5 -9.1 -19.4 -19.4 -19.4 -19.4 -19.4 -19.4 -19.3 -10.3	90.2 106.5 28.7 -8.1 111.4 225.1 112.6 171.9 54.1 48.6 106.0 123.6 45.2 91.1 105.1 29.6 -7.5 115.2 164.7 54.3 5.2 107.7 120.8 47.1 5.6 108.0 109.1 175.5 239.7 50.8 57.0 54.9 52.7	4.2 22.5 -6.3 -18.1 -4.6 -3.9 -3.4 -4.1 -21.9 25.6 15.0 16.6 28.2 2.1 12.1 -18.4 -22.5 3.2 6.7 13.7 -17.8 3.7 -14.4 3.0 -14.4 3.0 -14.4 3.0 -13.5 3.7 -50.2 -20.0 5.9 24.7	

^{*} Period between time-slice = .015 hr.
Negative conductances set to a small positive value for corrected model steady state temperatures.

Table 2-7. Correction Behavior of 16 Soft Conductances, 34-node Conventional Platform Correction Bounds <u>+</u> .9, KALFIL Cool-Down Condition

						Time-Sli	ces* ———			
Conductor #	r Description	Original Value Btu/hr °F	1 t = 0 hr	2	3	6	9	12	15	17 t = .24 hr
71	· .	75.	73.9	68.1	62.2	51.3	45.8	41.9	39.1	37.6
72	Î	75.	57.2	37.7	23.5	7.5	Bour	ided ———	7.5	7.5
72		37.5	39.8	9.9	3.75	Bour	ded	3.75	3.8	4.0
73	Conductance between heaterand	37.5	37.7	36.9	35.3	33.8	32.6	30.3	27.1	24.9
	n n h La t	100.	95.2	36.9	.10.0		Bounded		10.0	10.1
75	Cond twee nd p		75.1	73.7	71.5	64.8	59.4	54.9	50.7	48.3
76	- pe	75.		19.1	18.7	16.9	15.3	13.9	12.8	12.3
77 P		18.8	14.2		12.4	11.8	11.4	11.1	.11.0	11.0
<u> </u>	<u> </u>	18.8	14.1	12.9	12.4		,,,			
120	Ā	3.564 E-10	4.02 E-10	4.52 E-10	5.01 E-10	6.15 E-10	6.56 E-10	6.51 E-10	6.34 E-10	6.21 E-10
		1.192 "	1.29 "	1.38 "	1.47 "	1.67	1.70 "	1.62 "	1.52 "	1.46 "
121	출 자	3.554 "	4.24 "	5.14 "	6.18 "	6.77 "		— Bounded —		-6.77 " −
122	e twe sir	•	1.41 "	1.54 "	1.62 "	1.85 "	2.11 "	2.27 "	Bounded	→ 2.27 "
123	and band	1.132		1.36 "	1.34 "	1.73 "	1.91 "	1.34 "	.237 "	Bounded
124	Radiation between heater and sink	2.372 "	1.50		1.90 "	1.66 "	1.67 "	1.74 "	1.78 "	1.77 "
125	Radi hea	n .	2.24 "	_,,		5.92 "	5.14 "	5.52 "	6.87 "	8.01 "
126		6.342 "	6.81 "	7.41 "	7.23 "		1.18 "		- Bounded -	.474 "
127	À	4.749 "	4.55 "	4.24 "	3.86 "	2.50 "	1.10	. 47	. Dodinos	

^{*} Period between time-slice = .015 hr

temperatures, the correlation with test temperatures is far from perfect. For this particular case, there is also little to choose between KALØBS and KALFIL, although KALFIL appears to be a little better. The reason for the close results of KALØBS and KALFIL is the narrow bounding and the small number of soft parameters.

Better correlation between test and corrected model temperatures could probably have been attained with a better choice of soft parameters or a larger number of soft parameters. The latter is limited by the capacity of KALFIL and inaccuracy consideration of KALØBS. The important consideration here is that the 16 soft conductors selected in a somewhat arbitrary way must be adjusted to obtain a best fit correlation. Thus, the degree of adjustment is very limited.

Another consideration for the lack of correlation between test and corrected model temperatures is the inaccuracy of the functional form of If the functional form of the math-model does not the math-model. satisfactorily describe the physical system, correlation of analytical and test temperatures may require parameter values that are not physically realizable. For example, node 45 of the 34-node conventional platform can match test data only if a negative conductance (number 125) from the boundary to node 45 is used. The reason for this behavior becomes apparent by examining the nodal network. Node 45 is connected to node 9 which is cooler than node 45. Node 9 is connected to node 8 which is at a higher temperature than node 45. Thus, the effect of node 8 cannot be felt directly because of the intervening node 9. Even complete elimination of the heat loss to the boundary cannot overcome inaccurate modeling. A more realistic model would be a finer nodalization resulting in a shorter path to higher temperature node 8.

2.4 Correction Results with 41-Node Heat Pipe Platform Math-Model

Because of the similarity between the 34-node conventional platform and the 41-node heat pipe platform and the large number of parameters associated with the 41-node model, only a very limited number of correction evaluations were attempted. One of those studied was the correction

of 32 soft unbounded parameters using subroutine KALØBS. The sequential correction behavior of these soft parameters in terms of the number of time-slices are tabulated in Table 2-8. Note that only 24 of the specified 32 soft parameters were corrected since the remaining soft parameters were connected to nodes that in turn were connected to an unmeasured node. The correction, in general, was not accurate as indicated by the comparison of test, uncorrected and corrected model steady state temperatures as presented in Table 2-9. No attempt was made to use subroutine KALFIL because of rather lengthy computer run times.

2.5 Correction Results with 10-Node Conventional Platform Math-Model

The small size of the 10-node model provided a means of obtaining more exploratory information on the capabilities and limitations of both subroutines KALFIL and KALØBS, as well as to obtain some insight on those factors affecting the accuracy of the correction. The larger math-models were unsatisfactory for obtaining the desired information.

2.5.1 Comparison of Subroutine KALFIL and KALØBS

Considering all (22) of the conductances to be soft, bounded corrections, +3.0, -(1.0 - .00001G_o), were made with subroutines KALFIL and KALØBS with the cool-down test data as used for the larger models discussed in previous paragraphs. Sequential correction behavior in terms of the number of time-slices for KALFIL and KALØBS is tabulated in Tables 2-10 and 2-11, respectively. Thirty-five time-slices representing a time period of 0.51 hour are shown. Some of the conductances, such as 1, 2, and 9 of Table 2-10 and 1, 2 and 7 of Table 2-11, have apparently converged, whereas others, such as 7 and 10 of Table 2-10 and 16 and 24 of Table 2-11, appear to be oscillating. Still others, such as 11 and 16 of Table 2-10 and 4 and 25 of Table 2-11, appear to be converging asymptotically. The important consideration here is that the set of corrected parameters at each time-slice reflects the best solution for the period between the beginning (t = 0 hr) and a particular time-slice. Comparison of Tables 2-10 and 2-11 reveals that parameter values, in general, are relatively close with but a few exceptions. These few, such as conductors

Table 2-8. Correction of 32 Soft Parameters, 41-Node Heat Pipe Platform, Unbounded Corrections, KALFIL, Cool-Down Condition

			Time-Slices*									
Conductor No.	Description	Original Value Btu/hr °F	t = 0 hr	· 2	3	6	9	12	15	17		
55	A	7.59	4	5.76	4.79	3.91	3.67	3.55	3.47	3.45		
56		5.06		1.19	.58	.12	04	17	30	34		
· 57		12.66	ĺ	10.64	9.45	8.46	8.31	8.30	8.32	8.33		
58	İ	7.59		7.67	7.77	7.96	8.03	8.06	7.98	7.92		
59	\$ \$	7.59	-	6.71	5.25	.83	-1.71	-2.99	-3.65	-3.79		
60	Conduction Conductances	5.06		18.81	24.56	- 21.85	17.91	20.91	26.41	28.05		
61	cta	12.66		-5.11	-6.78	-44.4	-68.10	-77.62	-75.50	-72.81		
62	npu	7.59		6.83	6.09	5.12	4.77	5.70	9.65	11.73		
63	රි . -	2.53		2.39	2.27	2.12	2.07	2.04	2.03	2.03		
64	ioi	1.69	į	1.41	1.29	1.20	1.18	1.18	1.18	1.17		
65	uct	4.22		3.41	3.00	2.65	2.57	2.55	2.55	2.55		
66	puo;	2.53	and the second	1.82	1.46	1.14	1.07	1.06	1.06	1.06		
67	Ĭ	.90	sər									
68	***	.05	Original Values			Soft Pa	rameters Unco	orrected,		. (
69		.14	(G	•	,	Node Conne	ected to Unmea	isurea noae				
70	<u> </u>	.90	ņip	(}		
100	A	5.39 E-10	0r:	5.92 E-10	6.21 E-10	6.48 E-10	6.57 E-10	6.62 E-10	6.63 E-10	6.63 E-10		
101	on the same	3.60 "	a S	2.98 "	2.88 "	2.82 "	2.87 "	3.06 "	3.38 "	3.50 "		
102		8.99 "	Same	9.78 "	10.26 "	10.72 "	10.86 "	10.95 "	11.00 "	11.02 "		
103	100 m	5.39 "	. Sa	5.21 "	4.95 "	4.45 "	4.29 " -	4.27 "	4.28	4.28 "		
104	v v	.90 "	İ							}		
105	Radiation Conductances	.30 "		}			irameters Unco nected to Unme			5		
105	uct	.60 "				node com	recece co omin					
107	puo	.60 "		(, ,		
108	ن د	2.70 "		2.01 "	8.79 "	-2.48 "	-4.31 "	-5.20 "	-5.58 "	-5.66 "		
109	tio	.90	e de la companya de l	1.57 "	1.89 "	1.52 "	40 "	-3.66 "	-6.5 "	-7.13 "		
110	dia	3.00 "		.57 "	-3.36 "	-16.91 "	-27.93 "	-36.72 "	-44.13 "	-46.33 "		
111	1	3.00 "		2.41 "	1.81 "	.91 " .	.12 "	-1.21 "	-2.93 "	-3.52 "		
112	i	1.80 "		1.89 "	1.97 "	2.07 "	2.09 "	2.10 "	2.10 "	'2.10 "		
113	,	1.20 "		1.33 "	1.39 "	1.43 "	1.43 "	1.43 "	1.42 "	1.41 "		
114	1	3.00 "	Ļ	3.29 "	3.43 "	3.56 "	3.60 "	3.62 "	3.64 "	3.65 "		
115		1.80 "	V	2.01 "	2.12 "	2.22 "	2.25 "	2.27 "	2.28 "	2.29 "		

^{*} Period between time-slices = .015 hr.

Table 2-9. Comparison of Test, Uncorrected and Corrected Heat Pipe Platform Model Steady State Temperatures 32 Soft Conductances Corrected with Cool-Down Data, Unbounded KALDBS, 17 Time-Slices* of Data

		Uncorrect	ed Model	32 Soft Conductances				
Node #	T _T (°F)	Analytical	Difference (T _A -T _T)(°F)	Analytical T _A (°F)	Difference (T _A -T _T)(°F)			
<u> </u>	·	TA (°F)		'A ' '	· A · I / · /			
1	58.	75.8	17.8	77.5	29.5			
2	68.	76.5	8.Ŝ	74.9	6.9			
3	· 58.	63.4	5.4	67.4	9.4			
4	60.	58.5	-1.5	72.8	12.8			
5	86.	110.5	24.5	124.6	38.6			
6	154.	169.7	15.7	183.4	29.4			
7	92.	113.1	21.1	126.1	34.1			
8	89.	104.8	15.8	119.9	30.9			
9	83.	93.5	10.5	109.8	26.8			
10	122.	154.5	32.5	169.6	47.6			
11	86.	83.2	-2.8	94.6	8.6			
12	77.	58.2	-18.8	80.7	3.7			
13	69.	72.2	3.2	85.6	16.6			
14	89.	91.3	2.3	100.4	11.4			
15	65.	47.8	-17.2	54.9	-10.1			
16	52.	41.0	-11.0	52.0	0.0			
21	66.	78.5	12.5	84.9	18.9			
22	51.	77.5	26.5	106.4	55.4			
23	64.	65.0	. 1.0	70.7	6.7			
24	61.	60.1	9	74.3	13.3			
25	92.	114.7	22.7	129.8	37.8			
26	94.	119.6	25.6	135.1	41.1			
27	92.	113.1	21.1	128.2	36.2			
28	89.	106.7	17.7	122.0	33.0			
29	82.	94.8	12.8	129.2	47.2			
30	116.	146.6	30.6	168.2	57.2			
31	85.	84.2	8	116.3	31.3			
32	76.	59.6	-16.4	81.5	5.5			
33	73.	74.2	1.2	89.6	16.6			
34	96.	93.3	-2.7	104.5	8.5			
35	72.	49.3	-22.7	58.6	13.4			
36	59.	42.3	-16.7	56,4	~2.6			
41	82.	93.4	11.4	109.6	27.6			
42	85.	108.9	23.8	123.0	38.0			
43	129.	155.4	26.4	170.6	41.6			
44	165.	181.4	16.4	195.1	30.1			
45	81.	82.8	1.8	94.1	13.1			
46	88.	83.5	-4.5	94.8	6.8			
47	81.	83.2	2.2	94.5	13.5			
48	76.	58.0	-18.0	80.5	4.5			

Period between time-slices = .015 hour; Negative conductances set to a small positive value for corrected model steady state temperatures

Table 2-10. Correction Behavior of 22 Soft Conductance, 10-Node Platform Model, Correction Bounds, +3.0, -(1.0 - .00001 G_o), All Nodes Measured, Cool-Down Condition, KALFIL

	Time (hr)												
1				0	.015	.0600	.135	.21	.24	.285	.36	.435	.51
							7	ime-Slice	*				
Conductor #	Node, Node	Descript	ion Original Value Btu/hr °F	1	2	5	10	15	17	20	25	30	35
			5 Cd/111 1										
. 1	1, 2		.1	.102	.104	.107	.108	.107	.107	.108	.108	.109	.110
2	1, 3		.25	.252	.255	.25	.261	.26	.26	.259	.259	.258	.258
3	1, 4		.25	.249	.249	.248	.252	.258	.261	.265	.276	.283	.294
4	1, 6		10.	10.3	10.4	9.41	7.28	5.81	5.42	5.09	4.68	4.54	4.26
5 ·	2, 5	ŀ	.4	.403	.405	.408	.412	.412	.414	.416	,42	.42	.433
5	2, 7	nts	20.	19.7	18.1	11.2	5.67	4.82	4.75	4.77	4.89	4.98	5.14
. 7	3, 4	cj.	1.5	1.42	1.30	1.04	1.07	1.15	1.19	1.23	1.37	1.44	1.55
8	3, 8	ffi	5.0	5.55	5.67	3.87	2.15	1.59	1.50	1.47	1.51	1.54	1.62
9	4, 5	coe	.15	.154	.159	171	.173	.172	.172	.172	.171	.17	.17
10	4, 9	u u c	5.0	2.35	.53	.81	.85	.52	.42	.33	.37	.385	.391
	5, 10	Conduction Coefficients	40.	39.7	39.6	39.1	40.9	44.4	46.3	50.1	57.3	61.5	69.6
11 12	6, 7	лри	.1	.103	.107	.114	.112	.108	.107	.107	.107	.108	.109
	6, 8	Ō	.25	.262	.265	. 260	.263	.254	.245	.23	.20	.19	.16
13	6, 9	1	.25	.293	.30	.31	.302	.261	.254	.25	.267	.275	.286
14	7, 10		.4	.405	.42	.45	.486	.501	51	.53	.57	.59	.64
15	8, 9		1.5	1.80	1.84	1.90	1.75	1.52	1.43	1.36	1.28	1.25	1.16
16	9,10		.15	.186	.20	.20	.16	.108	.10	.09	.087	.087	.084
17	9, 10		•••								, , , , ,		1 0 275 10
21	1, 50	4.,	8.57 E-10	8.92 E-10	9.42E-10	10.48-10) 9.20E-11	9.27E-10
22	2, 50	on	17.14 "	16.4 "	15.4 "	13.4 "		12.85 "		13.8 "	74.7 "		15.9 "
23	3,50	Radiation Coefficient	8.57 "	9.66 "	11.1 "	14.0 "		12.33 "		11.6 "	11.4 "		11.2 "
24	4 , 50	ladi eff	8.57 "	9.22 "	10.2 "	12.1 "				11.0 "	10.1 "	9.66 "	9.05 "
25	5, 50	۳ ن ار	34.3 "	32.8 "	30.1 "	21.7 "	16.55"	16.80 "	17.1 "	17.7 "	18.4 "	18.8 "	19.5 "

^{*} Period between time-slice = 015 hr.

Table 2-11. Correction Behavior of 22 Soft Conductances, 10-Node Platform Model, Correction Bounds, +3.0, -(1.0 - .00001 G_o)
All Nodes Measured, Cool-Down Condition KALØBS

							125	Time (hr)	.285	.36	.435	.51
				0	.015	.0600	.135	.21	.24	.203	.30	.433	
Conductor	Node,Node i j	Description	Original Yalue Btu/hr °F	1	. 2	5	10	Time-Slic 15	e" 17	20	25	30	35
1	1,2		.1	——————————————————————————————————————	.100	.101	.102	.102	.102	.102	.102	.101	.101
2	1, 3	(7)	.25	ĵ	.250	.248	.246	.244	.244	.243	.243	.243	.242
3			.25	-	.248	.241	.238	.242	.246	.252	.262	.269	.272
4	1,4		10.	1	9.83	9.05	8.21	7.64	7.42	7.07	6.50	6.02	5.76
5	2,5	ĺ	4	-	.391	.385	.385	.388	.389	.391	.394	.397	.398
6 .	2, 7	Š	20.	ne ,	13.22	7.94	6.69	6.40	6.35	6.34	6.37	6.44	6.51
	3 , 4	Coefficients	1.5	Value	1.44	1.28	1.23	1.24	1.24	1.25	1.25	1.26	1.26
	3,8	<u></u>	5.0		4.78	4.09	3.73	3.67	3.65	3.67	3.68	3.69	3.71
8 9	4,5	oe f	.15	Original	.149	.147	.147	.148	.148	.148	.148	.143	.143
10	4, 9		5.0	Ori	4.48	3.39	3.87	3.76	3.74	3.74	3.81	3.87	3.89
11	5,10	Conduction	40.0	a S	35.14	23.88	19.33	18.83	18.95	19.26	19.80	20.09	20.04
12	6,7	onp	.1	Same	.099	.094	.086	.078	.074	.068	.057	.045	.038
. 13	6,8	Con	.25	-Sa	.254	.275	.307	.329	.336	.345	.355	.353	.367
14	6, 9	0	.25	į	.254	.277	.311	.330	.334	.337	.335	.325	.317
15	7,10		.4	i i	.402	.415	.455	.505	.525	.555	.600	.639	.667
16	8 , 9		1.5	Į	1.59	2.09	2.79	3.01	2.98	2.85	2.52	2.24	2.07
17	9,10		.15		.188	.313	.329	.297	.289	.282	,280	.284	.286
21	1 , 50	-	8.57 E-10		8.70 E-10 S	.29 E-10	9.88 E-10	10.07E-10	10.11E-10	10.04E-10	9.77 E-10		
22	2,50	an ts	17.14 "		18.57 " 19	72 "	20.09 "	20.38 "	20.51 "				21.90 "
23	3,50	icie	8.57 "		8.75 " 9	9.36 "	9.84 "	10.05 "	10.10 "	10.16 "			10.32 "
24	4 , 50	idia	8.57		8.10 " 7	7.47 "	7.58 "	7.94 "	8.00 "	7.99 "	7.87 "	7.75 "	7.73 "
25	5 , 50	Radiation Coefficients	34.3		32.7 " 28	3.55 n	25.38 "	22.99 "	22.11 "	20.91 "	19.28 "	18.24 "	17.87 "

^{*} Period between time-slice = .015 hr.

10 and 11 have relatively low sensitivity values as indicated by the sensitivity coefficients tabulated in Table E-1 of Appendix E. This is somewhat surprising since the results of KALØBS on the large models were very disappointing. It appears that the reasonably good result with KALØBS is due in a large measure to the small model.

An indication of the correction accuracy was obtained again by using the steady state temperatures corresponding to the test data of time-slice one. Steady state temperatures of the corrected 10-node model at time-slice 17 and 35 were generated and are tabulated in Table 2-12 for KALFIL and Table 2-13 for KALØBS along with the test and uncorrected model temperatures. The temperatures of the corrected model are much better than the uncorrected model. It should be noted that the solution at time-slice 17 differs from those at time-slice 35. Comparing Table 2-12 and Table 2-13, the results of KALFIL correlate better than those of KALØBS.

2.5.2 <u>Temperature Sparsity</u>

One of the important considerations in the evaluation of the thermal network correction program is the effect of temperature sparsity on the accuracy of correction. To obtain some sort of indication on the capability to correct soft parameters of a model that does not have temperature data for each math-model node, several different sparsity situations were studied using the 10-node math-model and subroutine KALFIL. These situations can be readily identified by referring to Figures A-8 and A-9. The first case considered was the elimination of a single node as a measured node that had the least effect on the total system; thus, node 10 was selected to be unmeasured. A second case eliminated a single measured node that had substantial influence on the total system; node 1 was selected. The last situation chosen was the elimination of a large number of measured nodes without having large pockets of uncorrectable parameters because of unobservability considerations; nodes 1, 5, 8 and 10 were selected.

Table 2-14 lists those corrected parameter values after 17 time-slices of data have been processed for the three temperature sparsity cases as well as for the case of complete temperature measurements. All but a few of the

Table 2-12. Comparison of Test, Uncorrected and Corrected 10-Node Platform Model, Steady State Temperatures, Cool-Down Condition, KALFIL, Bounds, 3.0 -(1.0 - .00001 G_o), All Nodes Measured

) ,		Uncorr	ected Model		22 Soft Conc Corrected		
Node #	Description	Test Data T _T (°F)	Model Temp. T _A (°F)	Difference (T _A - T _T) (°F)	17 Ti Temp. T _A (°F)	me-Slices Difference (T _A -T _T)(°F)	35 Ti Temp. T _A (°F)	me-Slices Difference (T _A -T _T)(°F)
1	· Jan	85.0	95.8	10.8	74.8	-10.2	83.6	-1.4
2	tform_ Heater)	22.5	10.2	-12.3	27.6	5.1	23.3	0.8
3	Plat ing l	107.4	148.8	41.4	109.6	2.2	129.6	22.2
4	oper Judi	187.4	200.7	13.3	191.7	4.3	204.3	16.9
5	Upper Pla (Including Nodes	51.6	32.6	-19.0	59.5	7.9	52.6	1.0
6	1	91.0	98.4	7.4	77.5	-13.5	86.9	-4.1
7	form	31.5	11.1	-21.4	31.6	0.1	27.7	-3.8
8	Plat ides	135.0	154.6	19.4	112.7	-22.3	129.3	-5.7
9	ower Plat Nodes	139.0	183.3	44.3	121.8	-17.2	134.9	-4.1
10		42.5	32.9	-19.6	59.3	16.8	52.5	10.0
50	Boundary	-50.0	- -	-	i e s			•

Table 2-13. Comparison of Test, Uncorrected and Corrected 10-Node Platform Model Steady State Temperatures, Cool-Down Condition, KALØBS, Bounds, +3.0, -(1.0 - .00001 G_o) All Nodes Measured

			Uncorrected	Mode1	Corr	ected Model (22	Soft Condu	ctances)
Nod #		Test Data T _T (°F)	Model Temp. T _A (°F)	Difference (T _A - T _T) (°F)	17 ti Temp. T _A (°F)	me-slices* (T _A -T _T)(°F)	35 ti Temp. T _A (°F)	me-slices* (T _A -T _A)(°F)
1	1 8	85.0	95.8	10.8	93.1	8.3	98.7	13.7
2		22.5	10.2	-12.3	14.5	-8.0	19.8	-2.7
3	r Tu	107.4	148.8	41.4	136.4	29.0	138.5	31.1
2-20	a H P	187.4	200.7	13.3	194.7	7.3	138.1	.7
, 5	 ₹	51.6	32.6	-19.0	52.9	1.3	61.6	10.
6		91.0	98.4	7.4	98.3	7.3	104.7	13.7
7	orm-	31.5	11.1	-21.4	18.1	-13.4	24.3	-7.2
8	Lower atform Nodes	135.0	154.6	19.4	145.5	11.5	148.3	13.3
9	<u> </u>	139.0	183.3	44.3	165.1	26.1	170.3	21.3
10		42.5	32.9	-19.6	53.5	-9.6	62.7	20.2
50	Boundary	-50.0				•		

^{*} Time between time-slices = .015 hr.

parameter values are approximately the same even for the high temperature sparsity situation. Those that are far different have low sensitivity as indicated by the sensitivity coefficients of Table E-1. Note that a few of the parameters were uncorrectable because of unobservability resulting from the presence of unmeasured nodes.

Using the parameter values listed in Table 2-14, steady state temperatures were calculated for each of the three temperature sparsity cases. The results are tabulated in Table 2-15 and compared with test data. These results show that even the extreme sparse conditions yielded much better correlation with test data than the uncorrected model. It is also apparent that the large sparsity situation yielded less accurate results than the other less sparse cases.

2.5.3 Interval Between Temperature Data Points

In a previous paragraph (2.1.2) a least squares method of interpolating recorded temperature data to obtain more frequent (time-wise) data was discussed. The important consideration in the selection of the interval between data points as discussed in Appendix B (Section B.2.1) is that the interval should not be considerably larger than the network solution computational interval. The basis for this statement lies in the computational procedure of the thermal network correction program. Since the network time-step normally is smaller than the temperature data interval, the thermal network correction program provides minimal parameter updating between temperature data points. This means that an optimum condition occurs when the network computational step is approximately the same as the test data interval. Since the network computational time-step continually changes during a transient solution, this optimum situation is difficult to obtain. Further, if the network solution time-step is very small, a large number of temperature data time-slices would be required to cover even a relatively small time period if the temperature data interval and the network solution time-step were approximately the same.

In order to obtain some indication on the effects of the temperature data interval on the correction accuracy, three different data intervals

Table 2-14. Comparison of Corrected 22 Soft Conductances for Different Sparsity Conditions, 10-Node Platform Model, Correction Bounds, +3.0, -(1.0 - .00001 G₀), KALFIL Cool-Down Condition

				Corre	Corrected Model, 17 time-slices,*t = .24 hr							
Conductor #	Node, Node i j	Description	original Value Btu/hr °F	All Nodes Measured Btu/hr °F	Node 10 Unmeasured Btu/hr °F	Node 1 Unmeasured Btu/hr °F	Nodes 1,5,8,10 Unmeasured Btu/hr °F					
1	1, 2		.1	.107	.108	.106	.109					
2 .	1, 3	Ĩ	.25	.26	.26	.264	.266					
3	1, 4		.25	.251	.261	.271	.271					
4	1, 6		10.	5.42	5.22	11.44	10.67					
5	2, 5	 	.4	.414.	.413	.412	.43					
6	2, 7	بن د	20.	4.75	4.41	5.03	3.12					
7	3, 4	Coefficients	1.5	1.19	1.17	1.17	1.10					
8 .	3,8	ښـ بـــ	5.0	1.50	1.50	1.73	2.55					
9	4, 5	Š	.15	.172	.173	.173	.159					
10	4, 9	Conduction	5.0	.42	.54	.364	.507					
11	5, 10	rct.	40.	46.3	35.4	46.8	Unobservable					
12	6, 7	onde	.1	.107	.107	.118	.120					
13	6,8	ٽ •	.25	.245	.246	.223	.217					
14	6, 9	į	.25	.254	.234	.241	.221					
15	7, 10		.4	.51	.44	.51	.424					
16	8, 9	l	1.5	1.43	1.43	1.44	2.30					
17	9, 10		.15	.10	.13	.103	.095					
21	1, 50	 د.	8.57 E-10	9.21 E-10	9.18 E-10	Unobservable	Unobservabl e					
2 2	2, 50	ion	17.14 "	13.2 "	12.9 "	13.7 E-10	9.36 E-10					
23	3, 50	Radiation Coefficient	8.57 "	11.9 "	12.0 "	12.3 "	12.6					
24	4, 50	Rad	8.57 "	11.4 "	11.5 "	11.8 "	11.6 "					
25	5, 50		34.3	17.1 "	18.0 "	17.4 "	Unobservable					
							•					

^{*} Period between time-slice = .015 hr.

Table 2-15. Comparison of Test, Uncorrected and Corrected 10-Node Platform Model, Steady State Temperatures, Cool-Down Condition Correction Bounds, +3.0, -(1.0 - .00001 G₀), KALFIL

	•		Uncor	rected Model		Co	Nodes 1,5,8,10					
Node #	e Description	Test Data T _T (°F)	Model Temp. T _A (°F)	Difference (T _A - T _T) (°F)	All Noo Temp. T _A (°F)	des Measured Difference (T _A -T _T)(°F)	Node 10 Temp. T _A (°F)	Unmeasured Difference (T _A -T _T)(°F)	Node 1 Temp T _A (°F)	Unmeasured Difference (T _A -T _T)(°F)	Unm Temp. T _A (°F)	easured Difference (T _A -T _T X°F)
1	<u> </u>	85.0	95.8	10.8	74.8	-10.2	74.7	-10.3	75.2	-9.8	72.6	-12.4
2	orm	22.5	10.2	-12.3	27.6	5.1	26.8	4.3	26.3	3.8	16.6	-5.9
3	latf g He es	107.4	148.8	41.4	109.6	2.2	109.5	2.1	107.1	3	105.0	-2.4
4	er p udin Nod	187.4	200.7	13.3	191.7	4.3	190.2	2.8	190.0	2.6	187.9	.3
- 5	Joi C.J	51.6	32.6	19.0	59.5	7.9	59.4	7.8	58.2	6.6	29.0	-21.6
. 6	·	91.0	98.4	7.4	77.5	-13.5	77.6	-13.4	76.2	-14.8	73.6	-17.4
_№ 7	tform	31.5	11.1	-21.4	31.6	0.1	30.8	7	30.2	-1.3	19.9	-11.6
2-23	latf les	135.0	154.6	19.4	112.7	-22.3	114.1	-20.9	109.0	-25.8	109.0	-30.0
9	, jo	139.0	183.3	44.3	121.8	-17.2	125.1	-13.9	116.7	-22.3	116.9	-22.1
10	Low	42.5	32.9	-19.6	59.3	16.8	59.3	16.8	58.0	15.5	29.2	-13.3
50	Boundary	-50.0	-				1					

^{*} Period between time-slice = .015 hr.

of .005 hours, .015 hour and .03 hour were examined using subroutine KALFIL. The network solution computational interval for the cool-down period was about .006 hour. The results are tabulated in Table 2-16. All of the parameter corrections were affected by the data interval. Approximately half of the corrected parameters were influenced very little; some were moderately influenced and a few were affected considerably by the time interval between data points. The latter consists of conductor numbers 6, 8, 10, 11 and 17. All of these conductances, with the exception of conductor 17, have relatively low sensitivity values as indicated by the sensitivity coefficients tabulated in Table E-1. The behavior of conductance 17 is not clear at this time.

Theoretically, the larger the number of time-slices the better are the results. This assumption was examined by comparing the steady state temperatures corresponding to the test data at time = 0 hour. These temperatures for the three different intervals are listed in Table 2-17. In general, the temperature at the smaller data interval correlate better than the longer intervals, but the differences are not large.

2.5.4 <u>Different Sets of Temperature Data</u>

All previous results were based upon a set of temperature data corresponding to a transient cool-down condition with no power generation. Another consideration that is particularly important is the use of a set of temperature data that corresponds to a different environmental condition. Since the correction technique represents the matching of the corrected model temperatures with a particular set of temperature data over a specified time period, it would be of particular interest to compare the correction of a model with a different set of temperature data. As a result, a heat up condition as described in Appendix B was employed. Temperature data used for this purpose is tabulated in Table B-3.

Using the same 10-node model exercised with the cool-down data, the twenty-two soft parameters were corrected with the heat up data; it should be noted that the heat sources were considered to be "hard." The results are tabulated in Table 2-18. Most of the conductors match very closely,

Table 2-16. Effect of Temperature Data Interval on Parameter Correction Accuracy, 10-Node Model, KALFIL, Bounded, + 3.0, -(1.0 - .00001 G₀), Cool-Down

						T	Time = .03 hr		7 ine = .05 hr		Time r .12 hr			Tine * .18 hr			-m			
	schotor rasr	ದಿಂದ (itode j	Description	Original Yalue Btu/hr *F	7 (.005 hr)	3 (.015 hr)	(.03 hr)	13 (.005 hr)	5 (.015 hr)	(.03 hr)	25 (.005 hr)	9 (.015 hr)	(.03 hr)	37 (.005 hr)	13 (.015 hr)	7 (.03 hr)	(.005 hr)	(.015 hr)	(.03 hr)
	,		2	Ā	.10	. 104	.105	.108	. 107	.107	. 109	.106	.108	.110	. 105	.107	.109	.105	. 107	.109
	•	,	3	Ĭ	.25	,255	.257	.259	.258	.260	. 262	.259	. 262	.263	, 257	.260	.262	. 255	.259	262
	3	,	4	ĺ	.25	.246	.249	.247	.248	.248	.247	.255	.251	.248	. 262	. 256	.250	.272	.261	.254
	,	,	8	i	10.00	9.44	10.21	10.86	7.75	9.41	10.43	5.74	7.75	9.25	4.63	6.32	8.04	4.304	5.468	3.96
		•	5		.40	.403	. 407	.411	.408	.498	.412	.416	.411	.413	.409	.412	.414	.408	.414	,416
	,	•	,		20.00	11.02	15.80	16,76	4,69	11.18	14.08	2.78	6.21	10.29	2.78	5.01	8.59	3.03	4.765	7.83
	•	3	4	. I	1.50	1.14	1.19	1.17	, 99	1.04	1.07	1.08	1.04	1.05	. 1.14	1.12	1.10	1.18	1.177	1.16
(m)		-	8	5	5.00	3.43	5.06	6.18	1.66	3.87	5.63	.82	2.43	4.48	.65	1.75	3.67	.673	1.514	3.21
Š	8	3	5	8	.15	.162	,164	,168	.170	.171	.173	.172	.174	.174	.172	.173	.174	.172	.172	.173
	9	•	-	į,	5.00	.272	.579	1.16	.598	.810	1.26	.560	. 906	1.43	.313	.662	1.28 .	.247	.438	.953
	10	4	9	ac t	40.00	31.73	39.35	39.12	20.53	39.13	39.41	6.33	40.24	40.71	1.26	42.82	42.29	5.40	46.37	43.9
	11	5	10	Ş		.108	.110	.116	.109	.114	,120	.106	.113	.120	.106	.109	.117	.108	107	.114
	12 .	6 .		1	.10	.255	.262	.278	.263	.260	.276	.270	.263	.270	.254	.260	.284	.219	.245	.251
	13	6	8		.25	.304	.304	.299	.319	.313	.304	.298	.312	307	.258	.276	.288	.305	.255	.262
	14	S	9	1	.25	.430	.428	.431	.463	.453	.447	.503	.483	.468	.546	.495	.474	.655	.511	.474
	15	7	10	- 1	.40		1.86	. 1.58	1.90	1.90	1,61	1.75	1.61	1.62	1.57	1.62	1.53	1.461	1.443	1.413
	16	8	9		1.50	1.91	.199	.213	.179	.199	.215	.126	.174	.205	.072	.126	.176	.044	.098	.145
	17	9	10	T	. 15	.108	.133		,,									9.10 E-10	9.25 E-10	9.65 E-10
	21	1	50	<u> </u>	8.57 E-10	9.72 E-10	9.69 E-10	10.34 E-10	10.12 E-10	10.38 E-1	0 10.71 E-10	9.51 E-10	10.12 E-10	10.54 E-10	9.05 E-10	9.50 E-10	10.07 E-10			12.72 "
	22	2	50	5 2	17.14 "	15.43 "	14.68 "	13.53 *	13.10 "	13.39 "	12.56 "	12.44 "	12.13 *	11.93 *	13.57	12.50 "	12.21 "	14.90	13.25	
	23	. 3	50	Rediction sefficients	8.57 "	11.76 "	12.37 *	13.73 "	13.28 "	14.03 *	15.00 "	12.62 "	14.14 "	15.17 "	11.28 "	12.86 *	14.21	10.56	11.98	13.22 "
	24	4	50	2 T	8.57 *	10.53	11.11 *	11.80 "	11.73 *	12.11	12.41 "	11.91 "	12,23 "	12.31 "	11.90 "	11.82 *	11.94	11.36 "	11.46	11.49 "
	25	5	50	ģ [≃]	34.3	26.89	27.13	25.55 "	19.60 "	21.73 *	21.55 "	15.35 "	16.96 "	17.76 "	16.69 *	16.56 "	17.34	16.58 *	17.18 *	17.72

Table 2-17. Comparison of Corrected Model Steady State Temperatures for Three Different Temperature Data Intervals Cool-Down, Correction Bounds, +3.0, $-(1.0 - 00001 G_0)$, KALFIL

Node #	Description	Test Data T _T (°F)	Uncor Temp. T _A (°F)	rected Model Difference (T _A -T _T)(°F)	9 Time-Slice Temp. T _A (°F)	Corns (At=.03 hr) Difference (TA-TT)(°F)	rected Model, 17 Time-Sli Temp. T _A (°F)	Time Period 0 to ces (Δt=.015 hr) Difference (T _A -T _T)(°F)	24 hr 49 Time- Temp. T _A (°F)	Slices (Δt=.005 hr) Difference (T _A -T _T)(°F)
1		85.0	95.8	10.8	72.9	-12.1	74.8	-10.2	78.2	-6.8
2	. Upper Platform Including Heater Nodes	22.5	10.2	-12.3	28.9	6.4	27.6	5.1	24.6	2.1
3	latf g He es	107.4	148.2	41.4	106.3	-1.3	109.6	2.2	117.2	8.8
4	er P udin Nod	187.4	200.7	13.3	183.4	-4.3	191.7	4.3	199.4	12.0
5	Upp	51.6	32.6	19.0	60.3	8.7	59.5	8.1	57.4	5.8
. 6		91.0	98.4	7.4	75.6	-15.4	77.5	-13.5	81.3	-9.7
7	form	31.5	11.1	-21.4	31.3	2	31.6	0.1	31.5	0.0
8	op at des	135.0	154.6	19.4	111.9	-23.1	112.7	-22.3	114.4	-20.5
9	Lower Platform Nodes	139.0	183.3	44.3	130.9	-8.1	121.8	-17.2	118.0	-21.0
10	, j	42.5	32.9	-19.6	60.3	17.8	59.3	16.8	55.3	12.8

Table 2-18. Comparison of Corrected Parameters, Cool-Down and Heat-Up Data, 10-Mode Model KALFIL, Bounds, +3.0 -(1.0 - .00001 $_{\rm O}$)

						Cooling	ductors-		22 Con	ductors		22 Condi	uctors	CON PARTS	22 Cor	iductors			iductorse>	~~ C>
Cond	ı. İ	Rode	Node	Description	Original Value Btu/hr °F	<0.015 hr ≈	1.01	5 hr	<0.06 hr≤>	5 Time-Slice	hr	⊠0.135 hrts- 10	Time-Slices	> Ut	-00.21 nr ==	5 Time-Slices		-0.24 nr 17	Tire-Slice:	2 mmscore
									.107	.102	.102	.108	.103	.103	.107	.104	.103	.107	.105	.104
1		1	2	ů	.1	.104	.101	.101		.255	.254	.261	.261	.258	.260	.264	.261	.260	.205	.261
. 2	•	1	3		.25	.255	.251	.251	.260 .248	.255	.261	.252	.299	.201	.258	.316	. 297	:261	.321	.301
3		1	4	4	.25	. 249	. 252	. 251	.248 9.41	9.72	9.70	7.28	8.80	8.61	5.81	8.03	7.79	5.42	7.85	7.55
4		1	6	1	10.	10.40	10.11	10.11 .401	,408	.401 .	.401	.415	.407	.409	.412	.419	.621	.414	.422	.423
5		2	5	ż	.4	.405	.401	19.37	.4V8	16.46	16.46	5.67	11.03	11.05	4.82	7.35	7.35	4.75	6.40	5.39
5		2	7	25	20.	18.1	19.37	19.37	1.04	1.42	13.44	1,07	1.27	1.19	1.15	1.19	1.13	1.19	1.17	1.12
. 7		3	4	£	1.5	1.30	1.45		3.87	6.43	6.48	2.15	5.35	5.70	1.59	4.77	5.21	1.50	4.65	5.06
3		3	8	ž	5.0	5.67	6.32	6.32		.167	.165	.173	.185	.173	.172	.168	.173	.172	.103	.173
ງ ⁹		6	5	ვ გ	.15	. 159	.155	.154	.171	.610	.602	.85	.531	.543	.52	.524	.541	.42	,524	.540
ינו ני ני ני		4	9	\$	5.0	.53	.782	.777 38.75	.81 39.1	29.25	29.21	40.9	9.47	9.39	44.4	2.31	2.43	46.3	1.49	1.61
٠٠' لو		5	10	ă	40.0	39.6	38.74		.114	.105	104	.112	.107	.106	.103	.107	.106	107	.107	.105
. 12		6	7	Ş	.1	.107	.102	.102			.293	.263	.312	.309	.254	.309	.305	.245	.307	.303
13		6	8	Ī	.25	.265	.269	.259	.260	.234	.295	.302	.336	.332	.263	.357	.353	.254	.351	.357
14		6	3	ĺ	.25	.30	.277	.277	.31	.297		.485	.485	.405	.501	.437	. 687	.510	.601	.481
15		7	10	ĺ	.4	.42	.405	.406	.45	.435	.435		.141	.165	1.52	.041	.020	1.43	.027	.074
16		Ð	9	ĺ	1.5	1.64	1.24	1.24	1.90	.592	.595	1.75		.173	.103	.190	.182	.10	.193	.185
17		9	10	¥	.15	.20	.168	.168	.20	.172	.171	.15	.179	.1/3	. 1.05	.150	. 102	. 10	.12	.103
21		1	50	An	8.57 E-10	. 9.42 E-10	8.75 E-10	8.75 E-10	10.4 E-10	8.92 E-10	8.90 E-10	9.87 E-10	8.78 E-10	8.47 E-1	0 9.32 E-10	8.45 E-10	7.89 E-10	9.2 E-10	8.31 E-10	7.72 E-10
22		2	Ĩ	88	17.14	15.4 "	16.59 "	16.69 "	13.4 "	15.99	15.99 "	12.11 "	14.14 *	14.13 "	12.85 "	12.51 "	12.48 "	13.2	12.97	12.03
23		3	1	10	8.57 *	11.1 "	9.04 "	9.03 "	14.0 *	10.13 "	9.93 "	13.73 ".	11.82 "	10.65 "	12.33 *	12.33 "	10.78	11.9 "	12.44	10.78 "
24		4	ð	25	8,57 "	10.2 "	9.22 "	9.19 *	12.1 *	11.34 *	10.63 "	11.99 "	14.45 "	11.66 "	11.65 "	15.46 *	11.79	11.4 *	15.57 "	11.79 "
25		5	J,	SRadiation⊖ Coefficients	34.3 "	30.1	32.73 "	32.73 *	21.7 "	28.44	28.52 "	16.55 *	23.70 *	24.18 *	15.89 *	23.99 "	24.51	17.1 "	24.37	29.87 *
	irce	•		¥																
4		-			329.6 Btu/hr	-	-	331.1	_	<u>-</u>	311.8			298.8		:	297.1			298.9
5		-	_		75.4	-	-	76.1	-	-	77.9	•	-	79.5			79.2			79.1

Period between time-slice = .015 hour.
22 soft conductors and 2 soft sources.

Table 2-19. Comparison of Corrected 10-Node Model Steady State Temperatures Cool-Down & Heat-Up Test Data, KALFIL Bounded +3.0, -(1.0 - .00001 G_o), 17 Time-Slices*

		•					Corr	ected Model -	ne ny fisiana kaominina dia kaominina dia mpikambana dia mpikambana dia mpikambana dia mpikambana dia mpikamban	the street of th
					Cool-	Down Data-	and the same of th	Heat-	22 Soft (Conductances
Node #	De cription	Test Data T _T (°F)	Uncorre Temp. T _A (°F)	cted Model Difference (T _A -T _T)°F	Temp. T _A (°F)	- 22 Soft Cor Difference (T _A -T _T)°F	nductors Temp. T _A (°F)	Difference (T _A -T _T)°F	& 2 So Temp. T _A (°F)	ft Sources Difference (T _A -T _T)°F
1		85.0	95.8	10.8	74.8	-10.2	70.8	-14.2	84.7	3
2	tform Heater	22.5	10.2	-12.3	27.6	5.1	21.3	-1.2	24.7	2.2
3	Jatt Ig He	107.4	148.2	41.4	109.6	2.2	88.8	-18.6	107.3	.1
	er P udir Nod	187.4	200.7	13.3	191.7	4.3	162.5	-24.9	188.9	1.5
2-28	Upper Plat	51.6	32.6	19.0	59.5	8.1	44.2	-7.2	46.7	-4.9
6	4	91.0	98.4	7.4	77.5	-13.5	72.5	-18.5	86.7	-4.3
7	tform	31.5	11.1	-21.4	31.6	0.1	23.8	-7.7	27.4	-4.7
8	latf es	135.0	159.6	19.4	112.7	-22.3	87.9	47.1	106.4	-28.6
. 9	er Plat Nodes	139.0	183.3	44.3	121.8	-17.2	110.9	28.1	129.7	-9.3
10	Lower	42.5	32.9	-19.6	59.3	16.8	45.6	3.1	49.3	6.8

^{*} Period between time-slices = .015 hour.

although several conductor values differ considerably. A complete one-to-one correlation was not expected because the corrected parameters can only reflect a given set of temperature data. Further, the cool-down results should be better than the heat up results merely from the fact that the heat up condition has heat sources as an additional area of uncertainty not present with the cool-down condition. This reasoning was explored by again correcting the 22 soft conductors in addition to the two heat sources of nodes 4 and 5. These correction results are tabulated in Table 2-18. The corrected conductors again, in general, are relatively close to the values determined for the other two cases. Note that the two soft sources have been corrected. At this stage it is difficult to assess the correctness of the conductors

Again using the steady state temperatures as a test of accuracy, the temperatures of the models corrected during cooling and heating were compared with the test data at time = 0 hour. These results tabulated in Table 2-19 reveal that indeed the correlation is better with the cool-down data correction that the heating data correction with just 22 soft conductors; the latter, in a general sense, is better than the uncorrected model. However, the heating data correction with the 22 soft conductors and 2 soft sources is better than the cooling data correction.

3.0 REFLECTIONS ON THE EVALUATION OF THE THERMAL NETWORK CORRECTION PROGRAMS

A number of factors, such as temperature data interval and temperature sparsity, and considerations, such as different sets of temperature data corresponding to different environmental conditions affecting thermal network correction, were explored by using math-models of a spacecraft-type platform. The exploration was separated into two major facets corresponding to the two thermal network correction subroutines KALØBS and KALFIL. The former was developed to correct a large network and the latter to correct a small network.

3.1 Subroutine KALØBS

Potential accuracy shortcomings on the use of subroutine KALØBS were recognized during the development of this program. As a result, a careful evaluation of this program was in order. A previous evaluation study with the use of computer-generated temperatures from a math-model yielded sufficiently encouraging results to pursue the evaluation further with test temperature data. The present study revealed that correction accuracy can be a problem when a large model is corrected with KALØBS; this inaccuracy appears to be due to error propagation from one node to another since for small models the parameter corrections are relatively good. In spite of accuracy difficulties with KALØBS, useful information on the functional form of the model can be obtained.

3.2 Subroutine KALFIL

Subroutine KALFIL, developed for small models or for larger models (less than sum of soft parameters and temperatures) with limited number of soft parameters, was evaluated with some success in a previous study using computer-generated temperatures. The present study with the use of test temperatures has again yielded good correction results. The evaluation explored the affect of several factors on the correction accuracy resulting in guideline information. In addition, the good correction results from different sets of test temperatures have greatly increased the possibility of KALFIL becoming a working analytical tool for correcting small models or other applications that require the solution of the inverse problem.

3.3 General Comments

The evaluation of correction subroutines required the use of some sort of criterion to indicate the correction accuracy. Certainly one measure would be to match transient temperatures for each node. Another method, and perhaps a more severe test, is the matching of steady state temperatures even though the correction was based on transient data. This approach which provided rapid visualization and comparison was adopted.

The evaluation did not attempt any nodal capacity correction because of two reasons: (1) subroutine KALFIL as presently programmed does not allow for the simultaneous correction of capacity and parameters on a given node although capacity can be corrected individually (subroutine KALØBS allows for this simultaneous correction); and (2) capacity of nodes is normally known accurately.

It should be noted that an in-depth examination was not made to ascertain the cause of temperature differences between test and corrected model temperatures. On the surface it appears that some of the differences are due to the inaccuracies of the functional form of the model, but perhaps a major consideration is the temperature data itself since a simple averaging procedure was used when more than one thermocouple was located in a given nodal region.

The results clearly indicate that if only a limited number of parameters are to be specified as soft, it is important that the parameters specified as hard be relatively accurate.

Future evaluation studies should consider the effects of factors such as temperature noise, parameter error estimate and should consider a more in-depth examination of different environmental conditions on the reproducibility of correction results. Future evaluation studies should examine in more depth causes of temperature differences between test and corrected model temperatures.

4.0 RECOMMENDATIONS

The evaluation of the thermal network correction programs with test temperatures has yielded sufficiently good correction results that a further evaluation study should be considered, especially with small models, since a number of useful applications can be anticipated. It is recommended that:

- (1) the effects of other factors such as temperature noise and and parameter error estimate be explored;
- (2) other systems with test temperatures be explored with both KALFIL and KALØBS;
- (3) the correction subroutines be improved by incorporating re-start capabilities, by improving input requirements, by incorporating simultaneous correction of capacity and parameters on a given node (KALFIL), etc.;
- (4) the correction inaccuracies be explored more fully by examining functional-form inaccuracies, temperature data inaccuracies, etc.;
- (5) the use of the correction programs for other applications such as model generation, simultaneous property measurements, etc., be explored.

5.0 REFERENCES

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- 5. J. D. Gaski, L. C. Fink and T. Ishimoto, "Systems Improved Numerical Differencing Analyzer Users Manual," TRW Systems Group, Report No. 11027-6003-R0-00, September 1970.

A. DESCRIPTION OF TWO TYPES OF PLATFORMS, MATH-MODELS AND TEST DATA

The two platforms used in the present study are identified as:

(1) conventional platform (platform without heat pipe); and (2) heat pipe platform. Physical characteristics of these platforms in the test configuration, math-model characteristics and test data are described in the sections to follow:

A.1 Platforms and Test Configuration

A.1.1 Physical Characteristics of the Two Platforms

Both platforms, after fabrication, were thermally identical except for the heat pipe/saddle insert in the heat pipe unit and the use of 0.051" facesheet thickness under the high heat dissipating components for the conventional platform; the nominal facesheet thickness used for the remainder of the conventional platform and throughout the heat pipe platform was 0.016". Weight of the conventional platform without packages was 6.2 lb and the heat pipe platform 10.8 lb for the same conditions. A schematic of the heat pipe platform is shown in Figure A-1; the conventional platform is the same except for the absence of the heat pipe.

The platform was constructed of an aluminum honeycomb structure one inch thick with 1/8 inch cells. One surface and the edges of the honeycomb were insulated with multilayer insulation as illustrated in Figures A-2 and A-3 to approximate adiabatic boundaries. Figures A-2 and A-3 also show the thermocouple locations of the conventional and the heat pipe platforms, respectively. Aluminum plates with heaters were used to simulated components. Outside surfaces of these plates were painted such that the hemispherical emittance = 0.86; unblocked areas on the platform had a hemispherical emittance = 0.86 (No. 850 aluminum Mylar tape).

The heat pipe used was a stainless steel water-filled pipe with a conventional wick system. Five wraps of 70 mesh screen was used in the evaporator and ten wraps of 70 mesh screen in the condenser.

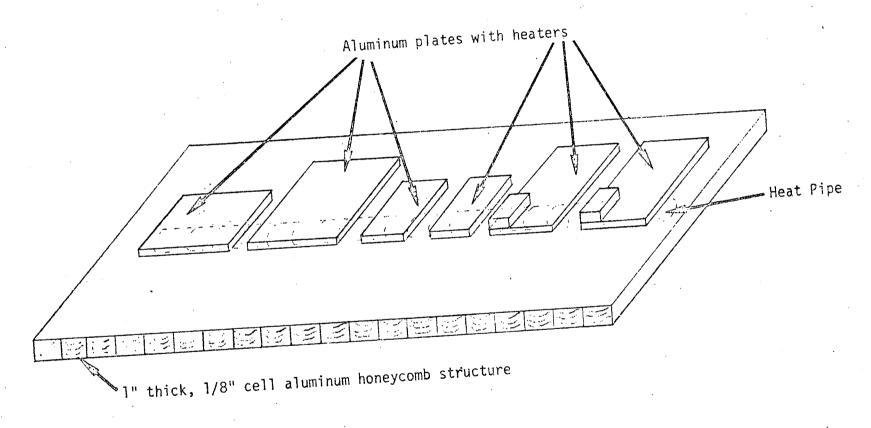


Figure A-1. Sketch of Heat Pipe Platform

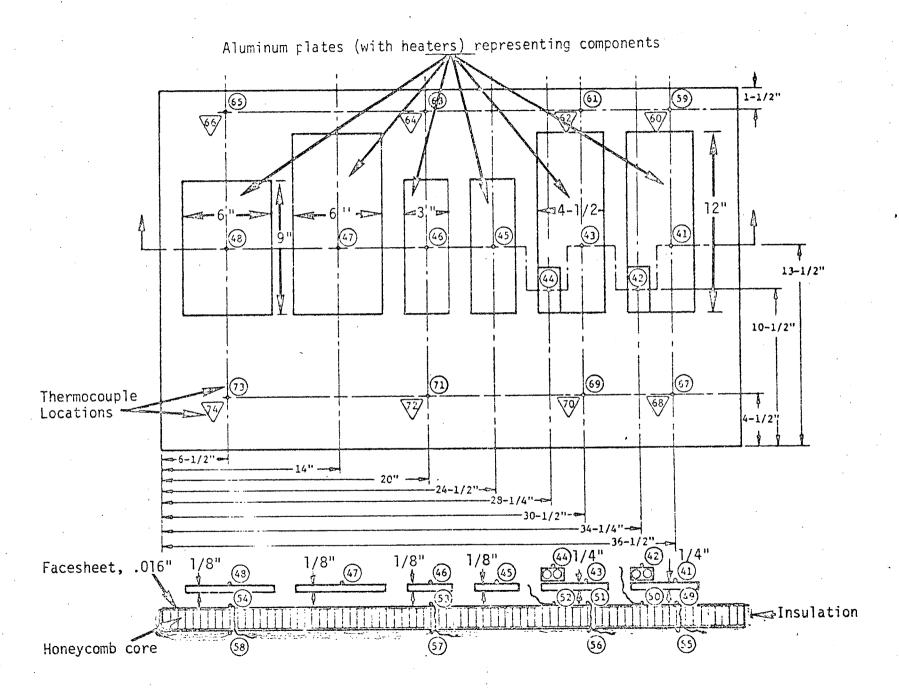


Figure A-2. Platform Without Heat Pipe Showing Heaters and Thermocouple Locations

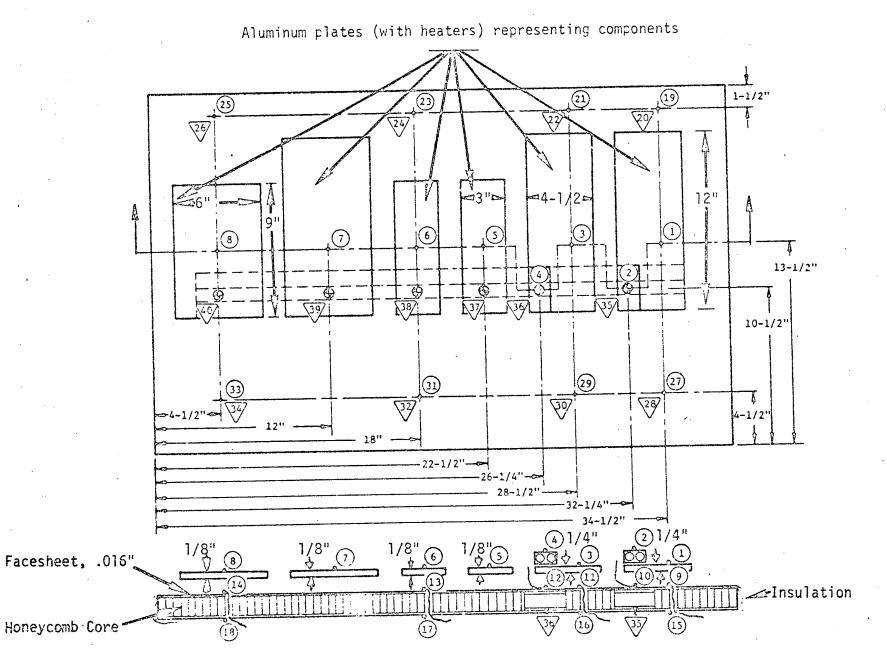


Figure A-3. Platform with Heat Pipe Showing Heaters and Thermocouple Locations

A.1.2 Test Configuration

Both the heat pipe platform and the conventional platform were tested simultaneously by mounting the platforms back-to-back with insulating standoffs and multilayer insulation in between as shown schematically in Figure A-4. With this arrangement the front side of the platforms and the simulated components radiated directly to the chamber walls which were cooled with a liquid refrigerant. The platform assembly was suspended in the chamber by the use of a dacron cord to minimize thermal interchange by conduction. Heat input to the components was furnished via heaters; no other heat sources such as a lamp were used. Thus, heat input to the simulated components was determined from current and voltage measurements. Temperature measurements were made with the use of copper-constantan thermocouples.

A.2 Mathematical Models of Conventional and Heat Pipe Platform

A.2.1 Conventional Platform Models

Thirty-Four (34) -Node Model

Location and number of temperature measurements on the conventional platform conveniently dictated a nodal arrangement illustrated in Figures A-5, A-6 and A-7, which also show in-plane connections and thermocouple locations. Nodal locations for the upper half of the platform, for the lower half of the platform and for the heaters are indicated in Figures A-5, A-6 and A-7, respectively. Variable temperature nodes numbered thirty-four; a single boundary temperature node representing the average cold sink temperature of the chamber wall was used. Complete math-model characterisitics are tabulated in Table A-1 and nodal connections in Table A-2.

Conductances used in the model were based on standard math-modelling procedures. No attempt was made to adjust conductance values manually in order to correlate better analytical and test temperatures.

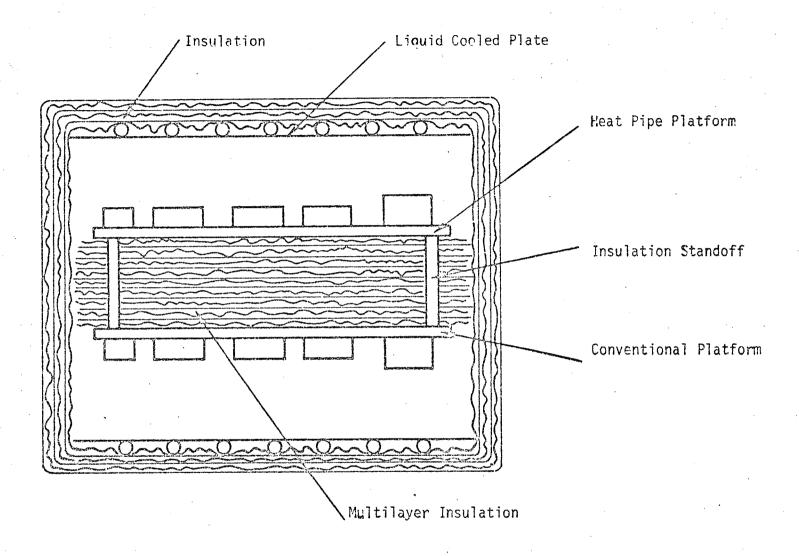


Figure A-4. Platform Test Configuration

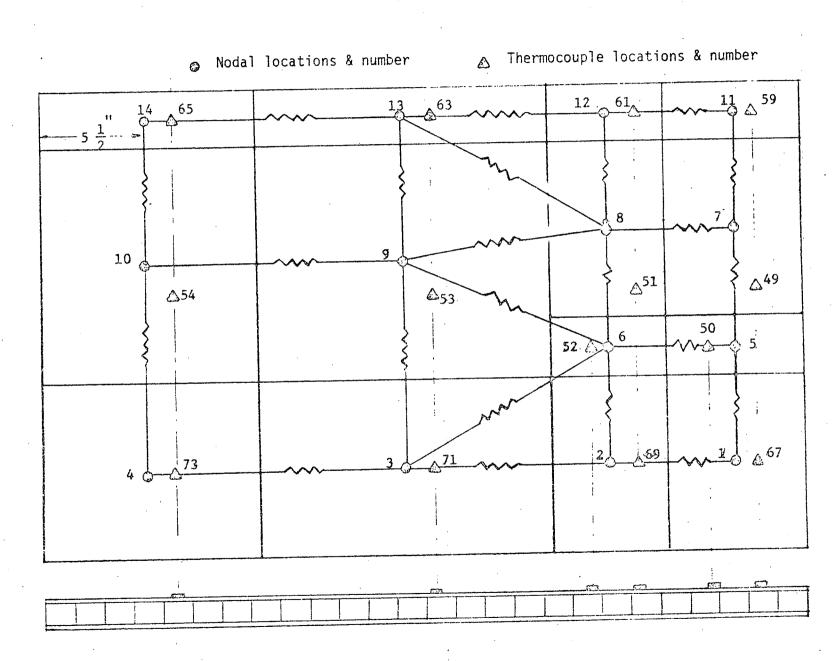


Figure A-5. Nodal Pattern of Upper Half of 34-Node Conventional Platform

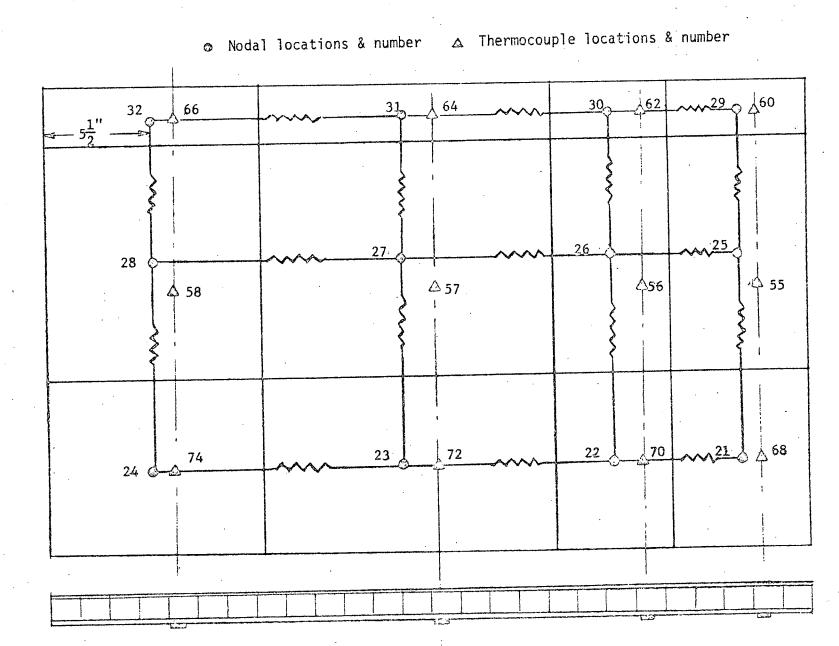


Figure A-6. Nodal Pattern of Lower Half of 34-Node Conventional Platform

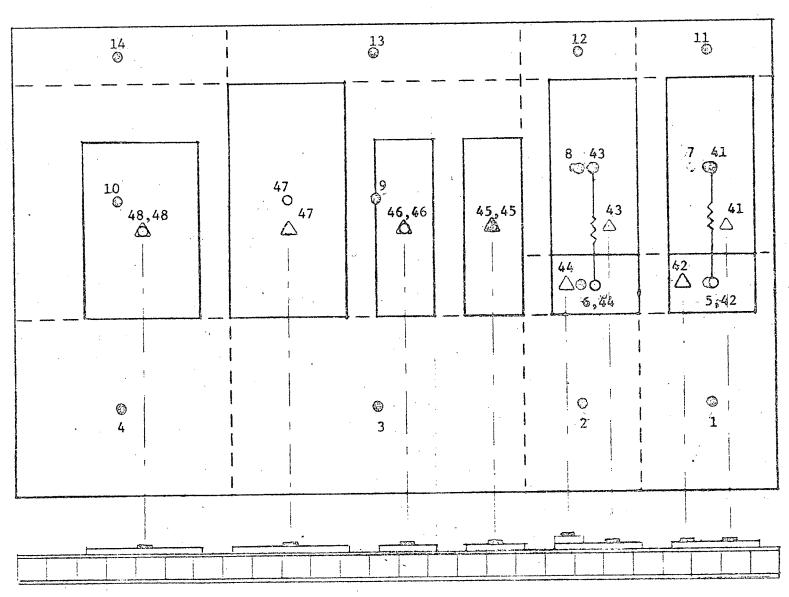


Figure A-7. Nodal Pattern of Heaters on 34-Node Conventional Platform

Table A-1. Characteristics of 34-Node Conventional Platform Math-Model

```
BCD BNODE DATA
 HEATER NODES
                           $ Actual node number, temperature (°F),
          44,80.,.09
                            heat capacity (Btu/°F)
          43,80.,.203
          46,80 ... 063
          47,80.,.13
          48,80.,.135
          41,80.,.203
          42,80.,.03
          45,800,0058
UPPER SURFACE, PLATFORM NODES
          5,80.,.043
          9,80.,.130
          7,80.,.145
          6,80.,.041
          8,80.,.124
          10,800,.104
          3,80.,.097
          1,80 ., . 145
          2,80.,.124
          4.80 . . C71
          13,80.,.032
          11,80.,.048
          12,80...041
          14,80.,.026
 LOWER SURFACE, PLATFORM NODES
          21,80.,.045
          22,80.,.039
          23,30.,.097
          24,80.,.071
          25,80.,.06
          26,80.,.052
          27,80.,.13
          28,80.,.10
          29,80.,.015
          30,80.,.013
          31,80.,.032
          22,80.,.025
 BOUNDARY NUDE
          -100, -60., 0.0
     BOD 3 SOURCE DATA
HEAT INPUT FOR TEST COMDITION THREE, STEADY STATE
                   $K1 = 0.0 Btu/hr
          41,K!
                    K2 = 0.0
          42,K2
                                ##
                   $ K3 = 81.9
          43.K3
                                11
          44,K4
                   $ K4 = 273.
          45,K5
                    K5 = 0.0
                   $ K6 = 24.9
                                ti
          46,K6
          47,K7
                   $ K7 = 36.5
                   $ K8 = 13.0
          48,KE
```

ENU

```
BCD 3CONDUCTOR DATA
UPPER SURFACE CUNDUCTION CONDUCTANCE
                      $ Conductor number, actual node number,
         1.1.2..557
                        actual node number, value (Btu/hr °F)
         2,2,3,0128
         3,3,4,.10?
         4,5,6,.22
         5,7,8,.557
         6,11,12,.22
         7, 4, 10, . 137
         8,12,13,.042
         9,12,14,.035
         10,8,13,.009
         11.8.9..077
         12,6,9,.055
         13,3,5,028
         14,1,5,.551
         15,5,7,.551
         16,7,11,.551
         17,2,6,0472
         18,6,8,.472
         19,8,12,.472
         20,3,9,.212
         21,9,13,.297
         22,4,10,.156
         23,10,14,.219
LUMER SURFACE CONDUCTION CONDUCTANCE
         51,21,22,0206
         32,22,23,.128
         33,23,24,.102
         34,25,26,.275
         35,26,27,.170
         36,27,28,0137
          37,29,30,.172
          39,30,31,.106
         39,31,32,.096
         40,21,25,.100
         41,25,29,.140
         42,22,25,0086
         43,26,30,.120
         44,23,27,.212
         45,27,31,.297
         46,24,28,.156
         47,28,32,.219
CONDUCTION CUMDUCTANCE BETWEEN UPPER ANNO LOWER SURFACES
          51,1,21,5,91
         52,2,22,5.06
          53,3,23,12.06
          54,4,24,9.23
          55,5,25,.43
          56,7,25,3.28
          57,0,26,037
          58,8,26,2.81
          59,9,27,16.88
         60,10,28,13.5
          61,11,29,1.97
          62,12,30,1.69
          63,13,31,4,22
          64,14,32,3.38
```

Table A-1. (Continued)

```
CONDUCTION CONDUCTANCE BETWEEN HEATERS AND UPPER SURFACE
        71,41,7,75.
        72,43,8,75 ...
        73,45,9,37.5
        74,46,9,37.5
        75,47,9,100.
        76,48,10,75.
        77,42,5,18.8
        78,44,6,13.8
CONDUCTANCE BETWEEN HEATERS
        79,42,41,1.41
        80,44,43,1.41
RADIATION COEFFICIENT, PLATFORM TO SINK
    CAL -100,1,100,.56,.437,1.714E-9,1.
    CAL -101,2,100,.56,.375,1.714E-9,1.
    CAL -102,3,100,.56,.937,1.714E-9,1.
    CAL -103,4,100,.56,.750,1.714E-9,1.
    CAL -104,5,100,.56,.052,1.714E-9,1.
    CAL -105,6,100,.56,.031,1.714E-9,1.
    CAL -106,7,100,.56,.156,1.714E-9,1.
    CAL -107,8,100,.56,.094,1.714E-9,1.
    CAL -108,9,100,.56,.375,1.714E-9,1.
    CAL -109,10,100,.56,.625,1.714E-9,1.
    CAL -111,12,100,.56,.125,1.714E-9,1.
    CAL -110,11,100, .56, .146, 1.7145-9,1.
    CAL -112,13,100,.56,.312,1.714E-9,1.
    CAL -113,14,100,.56,.250,1.714E-9,1.
RADIATION COEFFICIENT HEATERS TO SINK
    CAL -120,41,100,.74,.281,1.7145-9,1.
    CAL -121,42,100,.74,.094,1.714E-9,1.
    CAL -122,43,100,.74,.281,1.7146-9,1.
    CAL -123,44,100,.74,.094,1.714E-9,1.
    CAL -124,45,100,.74,.187,1.7142-9,1.
    CAL -125,46,100,.74,.187,1.714E-9,1.
    CAL -126,47,100,.74,.500,1.7149-9,1.
    CAL -127,48,100,.74,.275,1.71145-9,1.
    END
```

Table A-la, Second Nodal Arrangement of 34-Node Conventional Platform Math-Nodel

```
BCD 3NODE DATA
UPPER SURFACE, PLATFORM NUDES
                              $ Actual node number, temperature (°F),
          1,800,0145
                                heat capacity (Btu/°F)
          2.80.00124
          3,800,0097
          4,80000071
          5,800,0048
          6,80000041
          7,800,0145
          8,80.,0124
          9,800,0130
          10,800,0104
          11,800,0046
           12,80 . . . 641
           13.80 . . . 032
           14.80 . . . . . . . . . . . . .
 LOWER SURFACE , PLATFORM NUDES
          21,800,0045
          22,800,0039
           23,800,0097
           24.80 . . . 071
           25,800,000
           26,800,0052
           27,800.13
           28,80 . . . 10
           29,800,0015
           30.80 . . . 013
           31,800,0032
           32,800,0026
 HEATER NODES
           41,800,0203
           42,800,009
           43,800,0203
           44.8000009
           45,800,0068
           46,800,0068
           47.800.018
           48.80 . . . 135
  HOUNDARY NODE
           -100,-60.,0.0
      END
```

Table A-2. Nodal Connections of 34-Node Conventional Platform Math-Model

NODE	C-VALJE	CSG-VALUE	COND	TYPE	G-VALUE	TO NODE TYPE
44	9.000E-02	4.4426-03	7	1 T h l	1. 600 0040 1	6 DIFF
			7 d		1.880E+01	
			80		1.410E+00	
			-123	RAD	1.192E-10	I dd baan
: 43	2.030E-01	2.051E-03	70	LATA.	7.500E+01	ь DIFF
			72		1.4106+00	
	, , , - , ,		-80 -122		3.564E-10	
		5 00 E 03	-122	N,A O	J. 2016 10	
46-	6.800E-02	1.86086-03	74	Lini	3.750E+01	9 DIFF
			-125		2.372E-10	
; '	1.800E-01	1 7054-13	.* 5 1		77.	•
4 /	1.000E-01	1.776 03	75	LIN	1.0006+02	9 DIFF
			-126		6.342E-10	
7. 0	1.350E-01	7.7956-03	- L- '			
40	1.3300 01	101125	76	LIN	7.500E+01	10 DIFF
	•		-127	GAS	4.74 9E-10	100 BOUN
	2 030F-01	2.651E-03			•	
	2 9 0 2/19 1, 17 %		71		7.5UOF+01	
	•		7 9		1.4106+00	
	And the second second second second		-120	RAD	3.564E-10) 100 BOUN
42	9.000E-02	4.442E-03				· nrrr
1			77		1.880E+01	
	A CONTRACT MANUFACTURE OF		" 7 4		1.410E+00	
			-121	RAD	1.192E-10	0 100 BOUN
45	6.800E-02	1.8CsE-03		4 *	2. 75.00 (0)	1 9 DIFF
			7 3		3.750E+0	=
			-1.24	RAD	2.372E-1	0 - 100 BOUN
. 5	4.800E-02	2.333E-03			o'near a	1 6 DIFF
			4		2.2001-0	_
			14	LIN	5.51GL-C	
		•	15	LIN	5.510E-0 4.300E-0	
			55 77	LIN	1.880E+0	-
			1.06	LIN	4.991E-1	·
	. 1 3005 11	6.742E-04		MAD	4.6 2 2 2 2 2 2 2	1 100 5000
	7 1.300E-01	L 0 • (9/0 DTV4	7	1 IM	1.3708-0	1 10 DIFE
			11		7.7009-0	
			12		5.5C0E-0	
			20		2.120E-0	
			21		2.970E-0	
			54		1.638E+C	
			73		3.750E+C	1 45 DIFF
			74		3.7506+0	
•		• •	7 5		1.000E+0	
		•	-108	RAD	3.599E-1	0 100 BUUN

Table A-2. (Continued)

```
b DIFF
                               LIN 6.570E-01
                            5
                                                   5 DIFF
                               LIN 5.510L-01
                           15
                                                  11 DIFF
                               LIN 5.510F-01
                           16
                                                  25 DIFF
                               LIN 3.280E+00
                           56
                                                  41 DIFF
                               LIN 7.500E+01
                           71
                                                 100 BOUN
                               RAD 1.497E-10
                          -106
6 4.100E-02 2.0C7F-03
                                                    5 DIFF
                                LIN 2.200E-01
                                                    9 DIFF
                                LIN 5.500E-02
                           12
                                                    3 DIFF
                                LIN 2.800E-02
                           13
                                                   2 DIFF
                                LIN 4.720E-01
                           17
                                                   8 DIFF
                                LIN 4.720E-01
                            18
                                                   26 DIFF
                                LIN 3.700E-01
                            57
                                                   44 DIFF
                                LIN 1.680E+01
                            78
                                                  100 BUUN
                                RAD 2.976E-11
                          -105
8 1.240E-01 1.559E-03
                                                    7 DIFF
                                LIN 6.570E-01
                                                   13 DIFF
                                LIN 9.000E-03
                            10
                                                    9 DIFF
                                LIN 7.700E-02
                            11
                                                    6 DIFF
                                LIN 4.720L-01
                            18
                                                   12 DIFF
                                LIN 4.720E-01
                            19
                                                   26 DIFF
                                LIN 2.810E+00
                            53
                                                   43 D1FF
                                LIN 7.500E+01
                            72
                                                  100 BOUN
                                RAD 9.022E-11
                          -107
10 1.040E-01 1.165E-03
                                                    9 DIFF
                                LIN 1.370E-01
                             7
                                                    4 DIFF
                                LIN 1.500E-01
                            22
                                                   14 DIFF
                                LIN 2.190E-01
                            23
                                LIN 1.350E+01
                                                   28 DIFF
                            60
                                                   48 DIFF
                                 TIN 7.500E+01
                            74,
                                                  100 BOUN
                                 RAU 5.999E-10
                          -109
 3 9.700E-02 7.179E-03
                                                     2 DIFF
                                 LIN 1.280E-01
                             2
                                                     4 DIFF
                                 LIN 1.020E-01
                             .5
                                                     6 DIFF
                                 LIN 2.800E-02
                            13
                                                     9 DIFF
                                 LIM 2.120E-01
                             20
                                                    23 DIFF
                                 LIN 1.266F+01
                             53
                                                   100 BOUN
                                 RAD 8.994E-10
                          -102
 1 1.450F-01 1.487E-02
                                 LIN 6.570E-01
                                                     2 DIFF
                             1
                             14 LIN 5.510E-01
                                                     5 DIFF
                                                    21 DIFF
                                 LIN 5.9106+30
                             51
                                 RAD 4.1950-10
                                                   100 BOUN
                           -10%
   1.2401-01 1.9178-02
                                 LIN 6.570E-01
                                                     1 DIFF
                              1
                                                     3 DIFF
                                 LIN 1.280E-01
                              2
                                                     6 DIFF
                                 LIN 4.720E-01
                             17
                                 LIV 2.06 JE+60
                                                    22 DIFF
                             52
                                  RAD 3.599E-10
                                                   100 BOUN
                           -161
```

Table A-2. (Continued)

4 7.100E-02 7.213E-03		•	
4 701001-02 182131 03		LIN 1.020E-01	3 DIFF
1	22	LIN 1.560E-01	10 DIFF
•	54	LIN 9.280E+00	24 DIFF
The same are the contract of the same of t	-1.03	RAD 7.199E-10	100 BOUN
13 3.200E-02 6.765E-03	- 1113	NAD (81) JE 10	
13 3.200 = 02 0.100 = 03	8	LIN 4.200E-02	12 DIFF
	9	LIN 3.500E-02	14 DIFF
\	10	LIN 9.000E-03	8 DIFF
	21	LIN 2.970E-01	9 DIFF
The state of the s	63	LIN 4.220E+00	31 DIFF
	-112	RAD 2.995E-10	100 BOUN
11 4.800E-02 1.714E-02	1.17.	1/2/2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	
11 4.800E-02 1.714E-02	<u></u> 6 ·	LIN 2.200E-01	12 DIFF
	16	LIN 5.510E-01	7 DIFF
1	61	LIN 1.970E+00	29 DIFF
I company of the same of the s	-110	RAD 1.401E-10	100 BUUN
10 / 10 / 10 1 670.00	-110	KRD 14 TO II. 10	120 0001
12 4.100E-02 1.057E-02	6	LIN 2.200E-01	11 DIFF
of speed in decision of a different management of the speed property case is a supplied of the speed of the s		LIN 4.200E-02	13 DIFF
	19	LIN 4.720E-01	8 DIFF
<i>j.</i>	£2	LIN 1.690E+00	30 DIFF
The second secon	-111	KAD 1.200E-10	100 BOUN
	- 111		200 0001
14 2.600E-02 6.960E-03	9	LIN 3.500L-02	13 DIFF
	23	LTN 2.190E-01	10 DIFF
	64	LIN 3.380E+00	32 DIFF
	-113	RAD 2.400E-10	100 BOUN
21 4.500 E-02 7.239 E-03		NAD ZOTOJE TO	£ 00 . B 50. V
21 4,500 = 02 7,2391 = 03	31	LIN 2.060E-01	22 DIFF
	40	LIN 1.0G0E-01	25 DIFF
and the second s	51	LIN 5.910E+00	1 DIFF
22 3.900E-02 7.117E-03	· •		
22. 36,9000 02 161110 03	31	LIN 2.060E-01	21 DIFF
and the second s	32	LIN 1.280E-01	23 DIFF
	42	LIN 8.600E-02	26 DIFF
	52		2 DIFF
0 2 0 7005 02 7 4625-02			
23 9.700E-02 7.4C3E-03	. 32	LIN 1.280E-01	22 DIFF
the state of the s	. 33	LIN 1.020E-01	24 DIFF
	44	LIN 2.120E-C1	27 DIFF
	53	LIN 1.266E+01	3 DIFF
24 7.100E-02 7.444E-03			
24 /.1001-02 /.4441-03	33	LIN 1.020E-01	23 DIFF
	46	LIN 1.560E-01	28 DIFF
and the second s	54	LIN 9.280E+00	4 DIFF
20 - 2000 - 12 1 6230-02	4-ر		, 0.11
25 6.000E-02 1.420E-02	- 34	LIN 2.750E-01	26 DIFF
	40	LIN 1.000E-01	21 DIFF
		LIN 1.400E-01	29 DIFF
•	41 55	LIN 4.300E-01	5 DIFF
	56	LIN 3.280E+00	7 DIFF
	.50	FIM PASSOCION	

Table A-2. (Continued)

26.5.200E-02 1.357E-02	•		
EU Sezone oz ressite oz	34	LIN 2.750E-01	25 DIFF
	35	LIN 1.700E-01	27 DIFF
	42	LIN 8.600E-02	22 DIFF
	43	LIN 1.200E-01	30 DIFF
	57	LIN 3.700E-01	6 DIFF
	58	LIN 2.810E+00	8 DIFF
27 1.300 E-01 7.346 E-03			
,	35	LIN 1.700E-01	26 DIFF
	36	LIN 1.370E-01	28 DIFF
	44	LIN 2 (120E-01	23 DIFF
	45	LIN 2.970E-01	31 DIFF
•	54	LIN 1.688E+01	9 DIFF
28 1.000E-01 7.137E-03		and the second s	
	36	LIN-1-370E-01	27 DIFF
	46	LIN 1.560E-01	24 DIFF
The state of the s	47	LIN 2.190E-01	32 DIFF
	60	LIN 1.35UE+01	10 DIFF
29 1.500E-02 6.573E-03	2.7	1.15. 1. 7201. 02	20 0100
· · · · · · · · · · · · · · · · · · ·	37	LIN 1.720E-01	30 DIFF
it is a second of the second o	41	LIN 1.400E-01	25 DIFF
30 1.300E-02 6.226E-03	61	LIN 1.970E+00	11 DIFF
30 1.300 E-02 6.2.20 E-03		1 TN 1 7205 01	מל הזכר
	3 <i>1</i> 38	LIN 1.720E-01 LIN 1.060E-01	29 DIFF 31 DIFF
The second section of the second production of the second	43	LIN 1.200E-01	26 DIFF
	62	LIN 1.690E+00	12 DIFF
31 3.200 E-02 6.755 E-03	13/2	ETN 1:070E 00	12 0111
	33	TIN 1.060E-01	30 DIFF
	39	LIN 3.600E-02	32 DIFF
	45	LIN 2.970E-01	27 DIFF
in the control of the	63	LIN 4.220E+00	13 DIFF
32 2.600E-02 7.056E-03	•		
	39	LIN 8.600E-02	31 DIFF
	47	LIN 2.190E-01	28 DIFF
	64	LIN 3.380E+00	14 DIFF

Ten (10) -Node Model

In order to reduce computer computational time as well as to obtain some indication on the effects of nodal size on the network correction process, a small 10-node model was generated. Nodal locations for the upper half of the platform which has been combined with the heaters are indicated in Figure A-8 and for the lower half of the platform in Figure A-9. Ten variable temperature nodes and one boundary node representing the chamber cold sink temperature were employed. Complete mathmodel characteristics are tabulated in Table A-3 and nodal connections in Table A-4. Parameter values were obtained by combining the values used in the 34-node conventional platform math-model. No attempt was made to adjust conductance values manually in order to obtain better correlation between analytical and test temperatures.

A.2.2 Heat Pipe Platform Model

Location and number of temperature measurements on the heat pipe platform are somewhat different from the conventional platform because of the presence of the heat pipe. Nodal location and in-plane connections for the upper half of the platform, for the lower half of the platform and for the heaters are indicated in Figures A-10, A-11 and A-12. Forty nodes represented variable temperatures and a single node represented the average cold sink temperature of the chamber wall. It should be particularly noted that a single node is used to represent the vapor temperature within the heat pipe. Temperature of the vapor within the heat pipe was not measured because of extremely difficult instrumentation problems. Complete math-model characterisitics are tabulated in Table A-5 and nodal connections in Table A-6.

Conductances used in the heat pipe platform math-model were based on standard math-modelling procedure. No attempt was made to adjust manually conductance values in order to correlate better analytical and test temperatures.

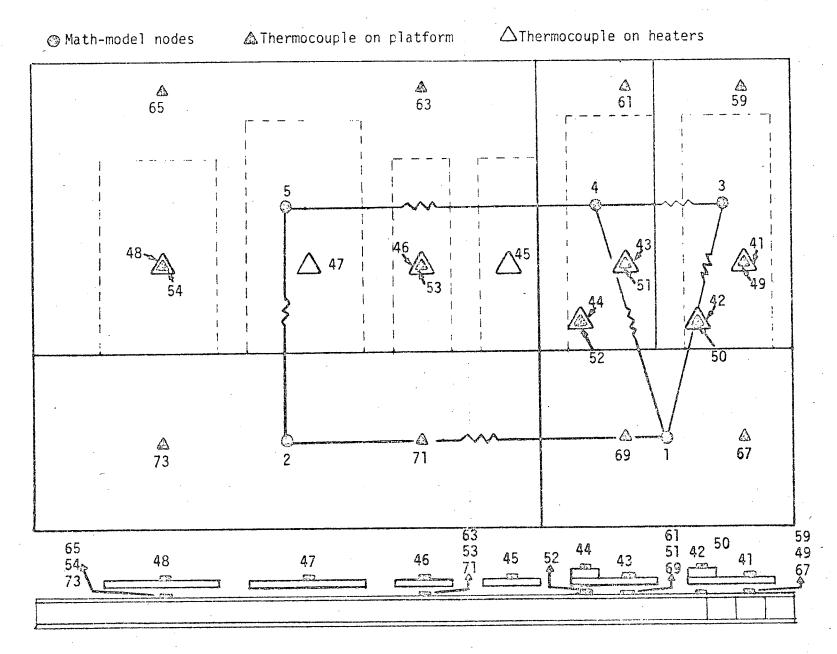


Figure A-8. Nodal Pattern and Thermocouples of Upper Half of 10-Node Conventional Platform and Heaters

Figure A-9. Nodal Pattern and Thermocouples of Lower Half of 10-Node Compentional Platform

A-20

Table A-3. Characteristics of 10-Node Conventional Platform

```
BCC 3NODE DATA
                        3 Node no., initial temp., capacity
       1,000,.269
       2,80.,.168
       3,800,534
       4,800,0418
       5,80,,.783
      6,8Co, C80
       7.80.,.168
       8,80.,.075
       5,800,0C65
       10,500,0262
       -50,-50.,C.O
   END
   BCD 3SOURCE DATA
              $K1 = 0.0 Btu/hr
       3,KI
              $ K2 = 355.0 "
       4,K2
              $ K3 = 74.0 "
       5.K3
   END
   BCD 3CONDUCTOR DATA
CONDUCTANCE CONDUCTANCE
       1,1,2,.1
       2,1,3,.25
       3,1,4,.25
       4,1,6,10.
       5,2,5,04
       6,2,7,20.
       7.3.4.1.5
       8,3,8,5.0
       9,4,5,015
       10,4,5,5.0
      .11,5,10,40.
       12.6.7..1
       13,6,8,.25
       14,6,9,.25
       15,7,10,.4
       10,8,9,1.5
       17,9,10,.15
RADIATION CONDUCTANCE, PLATFORM TO SINK
   CAL -21,1,50,1,,50,1,714E-9,1.0
   CAL -22,2,50,10,10C,10714E-9,100
   CAL -23,3,50,10,Co5,10714E-9,100
   CAL -24,4,50,10,Co5,10714E-9,100
   CAL -25,5,50,10,200,10714E-9,100
   END
```

Table A-4. Nodal Connections of 10-Node Conventional Platform

		CSG-VALUE	ŕ						•
ı	2.690E-01	2.451E-02		TYN	1.000	F=0T	2	DIFF	gane y majorgan en per errife. I
			2		2.500			DIFF	
			3.		2.500		_	DIFF	
					1:000		- 6	DIFF	
			-21		8.570			BOUN	
	1 4005-01	7.906E-03	- Kan - Ja				4 - 44		;
2	I. BOOK OI				1.000			DIFF	
			5		4.000			DIFF	
			5	LIN	2.000	E+01	<i>(</i>	DIFF	
	v - ·	ing in the protect of the second	-22	RAD	1.714	E-09	50	BOUN	
-4	5.34CF-01	7.456E-02							
_,	303,00 02		2		2.500			DIFF	
			7		1.500			DIFF	
			8		5.000			DIFF	
-	•		-23	RAD	8.570	E-10	50	BOUN	
4	4.180E-01	5.746E-02	_	,	2 500	VE_01	1	DIFF	
			3		2.500 1.500			DIFF	
			7		1.500			DIFF	
			9 · 10		5.000			DIFF	
			··· -24 ·		8.577			ROON	
,-		1.862E-02	~~~	KAU	0027		_	•	*
כ	1.0306-01	I COCZE OZ	5	LIN	4.000)E-01		DIFF	
		وأستراه والمستوار	9 -	LIN	1.500	DE-01		DIFF	
			11		4.000		-	DIFF	
			-25	RAD	3.42	8E-09	50	BOUN	
ć	8.000E-02	7.547E-03				a m . 0.1		DIFF	
			4		1.000			DIFF	
			12		2.50		-	DIFF	
•	,		13		2.50		9		
_		0 1055-03	14	FIIA	~ • J U		•		4
7	T. CROF-01	8.195E-03	٠٠٤	LTN	2.00	OE+OI	2	DIFF	
			12		1.00		6	DIFF	
			15	LIN	4.00	0E-01	10	DIFF	
ê	7.50CE-02	2 1.111E-02	· · · · · · · · · · · · · · · · · · ·						
•		* .	8	LIN	5.00	0E+00		DIFF	
			13	LIN	2.50	0E-01		DIFF	
		•	16	LIN	1.50	0E+00	ç	DIFF	
9	6.500E-0	2 9.420E-03	. ~		^^	<u>ለ</u> ፎኤ () ()		DIFF	
			10	L L iV	1 2 0 0 0 0	0E-01		DIFF	
	·	:		LIN	1 2 6 3 U 1 1 . KM	0E+00		DIFF	
			15 17			0E-01		DIFF	
	•		1.1	L. A 1					
10	1 3 4378 - 0	1 6.461E-03							
1 (, Z.EZUE-U	: 0040TE_03	11	LIN	4.00	0E+01	ï	5 DIFF	
		•	15	LIN	4.00	0E-01		7 DIFF	
						0E-01	(9 DIFF	•

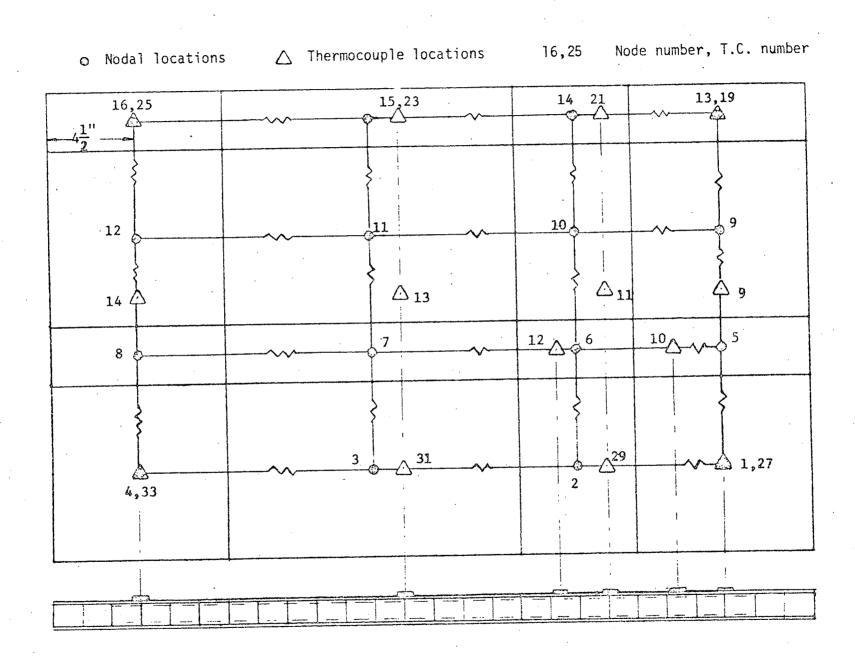


Figure A-10. Nodal Pattern of Upper Half of 41-Node Heat Pipe Platform

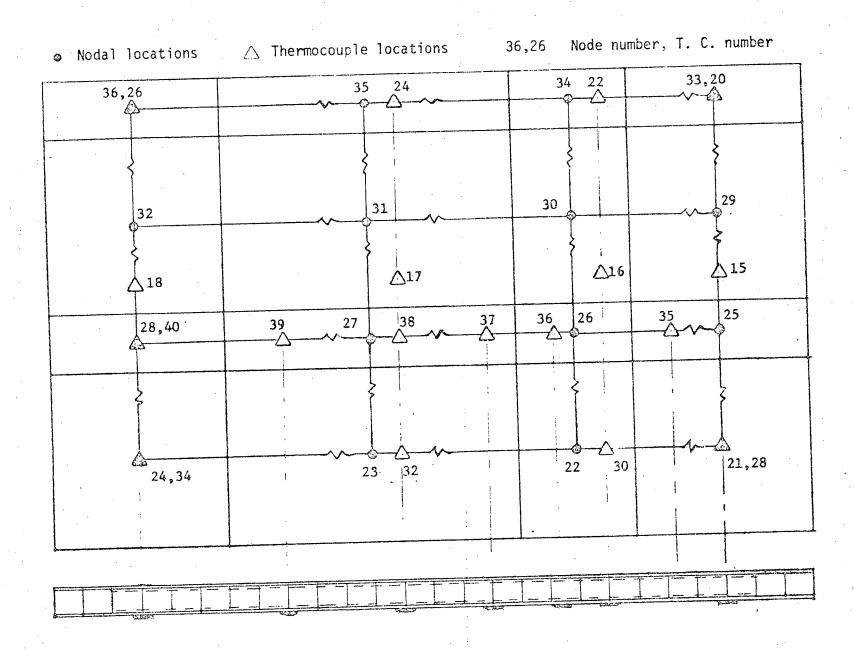


Figure A-11. Nodal Pattern of Lower Half of 41-Node Heat Pipe Platform

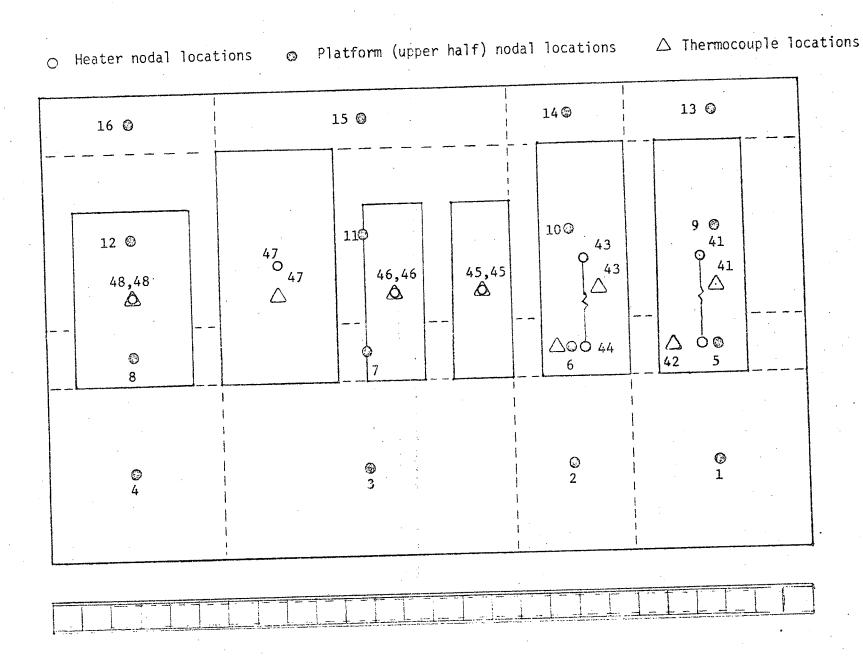


Figure A-12. Nodal Pattern of Heaters on 41-Node Heat Pipe Platform

Table A-5. Characteristics of 41-Node Heat Pipe Platform Model

```
BCD 3NODE DATA
UPPER SURFACE, PLATFORM MODES
                         $ PLATFORM NODES WITH NO HEAT PIPE NODES
          1,80,,.066
                         $ Actual node number, temperature (OF), heat capacity (Btu/OF)
          2,80.,.039
          3,80.,.097
          4,80.,.066
                         $ PLATFORM NODES WITH HEAT PIPE NODES
          5,80.,.042
          6,80.,.039
          7,80.,.194
          8,800,0042
          9.,80.,.066
          10,80.,.039
          11,80.,.097
          12,80.,.066
          13,80.,.019
          14,80.,.013
          15,80.,.032
          16,80.,.019
 LOWER SURFACE, PLATFORM NODES
                          $ PLATFORM NODES WITHOUT HEAT PIPE NODES . ..
          21,80.,.064
          22,80.,.039
          23,800,0097
          24,800,0066
          29,80.,.066
          30,80.,.039
          31,80.,.097
          32,80.,.066
          33.80.,.019
          34,80.,.013
          35,80.,.032
          36,800,019
                          $ PLATFORM NODES WITH HEAT PIPE NODES
          25,80.,.015
           26,80.,.012
           27,80.,.06
           28,80.,.015
  HEATER NODES,
           41,80.,.203
           42,800,009
           43,80 ... 2C3
           44,80 ... 09
           45,80.,.068
           46,80.,.068
           47,80.,.18
           48,30.,.135
  HEAT PIPE VAPOR NUDE
           50.80.0-1.
  BOUNDARY NODE
           -100,-60.,000
       END
```

```
BED 3 SOURCE DATA
HEAT INPUT, FOR TEST CONDITION THREE. STEADY STATE
        41061
                 $ K1 = 0.0
                             Btu/hr
                               11
        420 K2
                  $ 22 - 0.0
        43,K3
                  8 K3 = 81.9
        440K4
                 9134 - 273.0
        45, K5
                 $ K5 = 0.0 <
                               **
        46, K6
                 $ K6 $ 24.9
                               11
        470K7
                 $ K7 = 36.5
        48.K8
                  $ K8 = 13.0
    END
    BCD 3CONDUCTOR DATA
UPPER SURFACE CONDUCTION CONDUCTANCE, PARALLEL TO HEAT PIPE
                        S BEYWEEN NODES WITH NO HEAT PIPE NODES
         1,1,2,0179
        2,2,3,.128
        3,3,4,0112
        4,9,10,.179
        5,10,11,.128
        6,11,12,0112
         701301400060
         8,14,15,.042
        9.15,16,.037
         10.5.6.323 S BETHEEN HEAT PIPE NODES
         11,6,7,.231
         12,7,8,.202
UPPER SURFACE CONDUCTANCE, PERPENDICULAR TO HEAT PIPE
                         & HEAT PIPE NODES TO PLATFORM NODES
         14,2,6,.186
         15,3,7,.465
         16,4,8,028
         17,5,9,028
         18,6,10,.186
         19,7,11,0465
         20,8,12,.28
                        S BETHEEN PLATFORM NODES
         21,9,13,.18
         22,10,14,012
         23,11,15,.13
         24,12,16,.18
LOWER SURFACE CONDUCTANCE, PARALLEL TO HEAT PIPE
                         $ BETWEEN NODES WITH NO HEAT PIPE NODES
         31,21,30,.179
         32,22,23,.128
         33,23,24,.112
         34, 29, 30, .179
         35,30,31,.128
         36,31,32,.112
         37, 33, 34, .06
         38, 34, 35, .042
         39, 35, 36, .037
                         $ BETWEEN HEAT PIPE NODES
         40,25,26,.10
         41,26,27,0071
         42,27,28,.063
```

```
LOWER SURFACE CONDUCTANCE, PERPENDICULAR TO HEAT PIPE
                          & HEAT PIPE MODES TO PLATFORM NODES
         43,21,25,.24
         44,22,20,016
         45,23,27,.40
         46,24,28,.24
         47,25,29,.24
         48,26,30,.16
         49,27,31,.40
         5C, 28, 32, .24
                         $ BETWEEN PLATFORM NODES
         51,29,33,.18
         52,30,34,,12
         53,31,35,.13
         54,32,36,.18
CONDUCTION CONDUCTANCE BETWEEN UPPER AND LOWER SURFACE
                            $ BETWEEN HUNEYCOMB NODES
         55, 1, 21, 7.59
         56,2,22,5.06
          57, 3, 23, 12, 66
          58,4,24,7,59
          59,9,29,7.59
         60,10,30,5.06
          61,11,31,12.66
          62, 12, 32, 7, 59
          63, 13, 33, 2, 53
          64,14,34,1.69
          65, 15, 35, 4, 22
          06, 16, 36, 2.53
                          5 BETWEEN HEAT PIPES
          67,5,25,.90
          68,6,25,.05
          69,7,27,.14
          7C,8,28,.90
 CONDUCTION CONDUCTANCE BETWEEN HEATERS AND UPPER SURFACE
          71.41.9.75.
          72,43,10,75.0
          73,45,11,37.5
          74,46,11,37.5
          75,47,11,100.0
          76,48,12,75.
          77,42,5,18.8
          78,44,6,18.8
 CUNDUCTANCE BETWEEN HEATERS
          75,42,41,1.41
          80,44,43,1.41
 CONDUCTANCE BETWEEN VAPOR AND HEAT PIPE NODES
                           $ UPPER PLATFURM-EVAPORATOR END
          91,50,5,3,22
                           $ UPPER PLATFORM-EVAPURATOR END
          92,50,6,3.22
                           $ UPPER PLATFURM-CONDENSER END
          93,50,7,4.50
                           & UPPER PLATFORM-CONDENSER END
          94,50,8,1.80
                            $ LOWER PLATFORM-EVAPORATOR END
          95,50,25,3.22
                            $ LOWER PLATFORM-EVAPORATOR END
          96,50,26,3,22
                            & LOWER PLATFORM-CONDENSER END
          97,50,27,4.50
                            $ LOWER PLATFORM-CONDENSER FND
           98,50,28,1.80
```

```
RADIATION COEFFICIENT, PLATFORM TO SINK
    CAL -100,1,100,.56,.562,1.714E-9,1.
    CAL -101,2,100,.56,.375,1.714E-9,1.
    CAL -102,3,100,056,0937,10714E-9,10
    CAL -103,4,100,056,0562,10714E-9,10
    CAL -154,5,100, .56, .094,1.714E-9,1.
    CAL -105,6,100,.56,.031,1.714E-9,1.
    CAL -106,7,10C, .56, .062, 1.714E-9, 1.
    CAL -107,8,100,.56,.062,1.714E-9,1.
    CAL -108,9,100,.56,.281,1.714E-9,1.
    CAL -139,10,100,056,094,1,7146-9,1,
    CAL -111,12,100,.56,.312,1.7141-9,1.
    CAL -110,11,100,.56,.312,1.714E-9,1.
    CAL -112,13,100,.56,.187,1.714E-9,1.
    CAL -113,14,100,.56,.125,1.714E-9,1.
    CAL -114,15,100,.56,.312,1.714E-9,1.
    CAL -115,16,100,.56,.187,1.714E-9,1.
RADIATION CUEFFICIENT HEATERS TO SINK
    CAL -120,41,100,074,0281,1.714E-9,1.
    CAL -121,42,1CD,,74,,094,1,714E-9,1,
    CAL -122,43,100,.74,.281,1.714E-9,1.
    CAL -123,44,1C0,074,094,10714E-9,10
    CAL -124,45,100,.74,.187,1.714E-9,1.
    CAL -125,46,100,.74,.187,1.714E-9,1.
    CAL -120,47,100,.74,.500,1.714E-9,1.
    CAL -127,48,100,.74,.375,1.7114E-9,1.
    END
```

Table A-6. Nodal Connections of 41-Node Heat Pipe Platform Model

				And the second second	
NODE		HE CSGMIN			
NODE	C-VALUE	CSG-VALUE	COND	TYPE G-VALUE TO	NODE TYPE
	1 6.600E-02 7	7.973E-03	1 13 55 -100	LIN 1.750E-01 LIN 2.800E-01 LIN 7.590E+00 RAD 5.394E-10	2 DIFF 5 DIFF 21 DIFF 100 BOUN
	2 3.900E-02 (5.835E-03	1 2 14 56	LIN 1.790E-01 LIN 1.280E-01 LIN 1.860E-01 LIN 5.060E+00 RAD 3.599E-10	1 DIFF 3 DIFF 6 DIFF 22 DIFF 100 BOUN
	3 9.700E-02	7.056E-03	-101 2 3 15 57 -102	RAD 3.599E-10 LIN 1.280E-01 LIN 1.120E-01 LIN 4.650E-01 LIN 1.266E+01 RAD 8.994E-10	2 DIFF 4 DIFF 7 DIFF 23 DIFF 100 BOUN
	4 6.600E-02	8.038E+03	3 16 58 -103	LIN 1.120E-01 LIN 2.800E-01 LIN 7.590E+00 RAD 5.394E-10	3 DIFF 8 DIFF 24 DIFF 100 BOUN
	5 4.200E-02		10 13 17 67 77 91 -104	LIN 3.230E-01 LIN 2.800E-01 LIN 2.800E-01 LIN 9.000E-01 LIN 1.880E+01 LIN 3.220E+00 RAD 9.022E-11	6 DIFF 1 DIFF 9 DIFF 25 DIFF 42 DIFF 50 ARTH 100 BOUN
	6 3.900E-02		10 11 14 18 68 78 92 -105	LIN 3.230E-01 LIN 2.310E-01 LIN 1.860E-01 LIN 1.860E-01 LIN 5.600E-02 LIN 1.880E+01 LIN 3.220E+00 RAD 2.976E-11	5. DIFF 7 DIFF 2 DIFF 10 DIFF 26 DIFF 44 DIFF 50 ARTH 100 BOUN
	7 1.9405-01	3.213E-02	11 12 15 19 69 93 -106	LIN 2.310E-01 LIN 2.020E-01 LIN 4.650E-01 LIN 4.650E-01 LIN 1.400E-01 LIN 4.500E+00 RAD 5.951E-11	6 DIFF 8 DIFF 3 DIFF 11 DIFF 27 DIFF 50 ARTH 100 BOUN

```
8 4.200 E-02 1.204 E-02
                                                    7 DIFF
                                LIN 2.020E-01
                            12
                                                    4 DIFF
                                LIN 2.800E-01
                            16
                                                   12 DIFF
                                LIN 2.800E-01
                            20
                                                   28 DIFF
                                LIN 9.000E-01
                            70
                                                   50 ARTH
                                LIN 1.800E+00
                            94
                                                100 BOUN
                          -107 RAD 5.951E-11
9 6.600E-02 7.919E-04
                                                   10 DIFF
                                LIN 1.790E-01
                             4
                                                   5 DIFF
                                LIN 2.800E-01
                            17
                                                   13 DIFF
                                LIN 1.800E-01
                            21
                                                   29 DIFF
                                LIN 7.590E+00
                            59
                                                   41 DIFF
                                LIN 7.500E+01
                            71
                                                  100 BOUN
                                RAD 2.697E-10
                          -1.08
10 3.900E-02 4.832E-04
                                                    9 DIFF
                                LIN 1.790E-01
                             .4
                                                   11 DIFF
                                LIN 1.280E-01
                             5
                                                    6 DIFF
                                LIN 1.860E-01
                             18
                                                   14 DIFF
                                 LIN 1.200E-01
                             22
                                                   30 DIFF
                                 LIN 5.060E+00
                             60
                                                   43 DIFF
                                 LIN 7.500E+01
                             72
                               RAD 9.022E-11
                                                  100 BOUN
                          -109
11 9.700E-02 5.143E-04
                                                    10 DIFF
                                 LIN 1.280E-01
                              5
                                                    12 DIFF
                                 LIN 1.120E-01
                              6
                                                    7 DIFF
                                 LIN 4.650E-01
                             19
                                                    15 DIFF
                                 LIN 1.300E-01
                             23
                                                    31 DIFF
                                 LIN 1.266E+01
                             61
                                                    45 DIFF
                                 LIN 3.750E+01
                             73
                                                    46 DIFF
                                 LIN 3.750E+01
                             74
                                                    47 DIFF
                                 LIN 1.000E+02
                             75
                                                   LÕO BOUN
                                 RAD 2.995E-10
                           -110
12 6.600E-02 7.924E-04
                                                    11 DIFF
                                 LIN 1.120E-01
                              6
                                                     8 DIFF
                                 LIN 2.800E-01
                             20
                                                    16 DIFF
                                  LIN 1.800E-01
                             24
                                                    32 DIFF
                                  LIN 7.590E+00
                             62
                                                    48 DIFF
                                  LIN 7.500E+01
                             76
                                                   100 BOUN
                                  RAD 2.995E-10
                            -111
 13 1.900E-02 6.676E-03
                                  LIN 6.000E-02
                                                    14 DIFF
                              .7
                                  LIN 1.800E-01
                                                     9 DIFF
                             21
                                                    33 DIFF
                                  LIN 2.530E+00
                             63
                                                   100 BOUN
                                  RAD 1.795E-10
                           -112
 14 1.300E-02 6.623E-03
                                  LIN 6.000E-02
                                                     13 DIFF
                              7
                                                     15 DIFF
                                  LIN 4.200E-02
                              -8
                                  LIN 1.200E-01
                                                     10 DIFF
                              22
                                  LIN 1.690E+00 .
                                                     34 DIFF
                             64
                                                    100 BOUN
                                - RAD 1.200E-10
                           -113
```

```
15 3.200E-02 7.024E-03
                                                    14 DIFF
                                 LIN 4.200E-02
                              8
                                                    16 DIFF
                                 LIN 3.700E-02
                              9
                                                   11 DIFF
                                 LIN 1.300E-01
                             23
                                                   35 DIFF
                                 LIN 4.220E+00
                             65
                                                  100 BOUN
                                 RAU 2.995E-10
                          -114
16 1.900E-02 6.730E-03
                                                    15 DIFF
                             Q
                                 LIN 3.700E-02
                                                    12 DIFF
                                 LIN 1.800E-01
                             24
                                                    36 DIFF
                                 LIN 2.530E+00
                             66
                                                   100 BOUN
                                 RAD 1.795E-10
                           -115
21 6.400E-02 7.991E-03
                                                    30 DIFF
                                 LIN 1.790E-01
                             31
                                                    25 DIFF
                                 LIN 2.400F-01
                             43
                                                     1 DIFF
                                 LIN 7.590E+00
                             55
22 3.900E-02 7.292E-03
                                                    23 DIFF
                                 LIN 1.280E-01
                             32
                                                    26 DIFF
                                 LIN 1.600E-01
                             44
                                                     2 DIFF
                             56
                                 LIN 5.060E+00
23 9.700E-02 7.293E-03
                                                    22 DIFF
                                 LIN 1.280E-01
                             32
                                                    24 DIFF
                                 LIN 1.120E-01
                             33
                                                    27 DIFF
                                 LIN 4.000E-01
                             45
                                                     3 DIFF
                                 LIN 1.266E+01
                             57
24 6.600E-02 8.310E-03
                                 LIN 1.120E-01
                                                    23 DIFF
                             33
                                                    28 DIFF
                                 LIN 2.400E-01
                             46
                                                     4 DIFF
                                 LIN 7.590E+00
                             58
29 6.600E-02 8.060E-03
                                 LIN 1.790E-01
                                                    30 DIFF
                             34
                                                    25 DIFF
                             47
                                 LIN 2.400E-01
                                                    33 DIFF
                                 LIN 1.800E-01
                             51
                                                     9 DIFF
                                 LIN 7.590E+00
                             59.
30 3.900E-02 6.694E-03
                                                    21 DIFF
                                 LIN 1.790E-01
                             31
                                                    29 DIFF
                             34
                                 LIN 1.790E-01
                                                    31 DIFF
                             35
                                  LIN 1.280E-01
                                  LIN 1.600E-01
                                                    26 DIFF
                             48
                                                    34 DIFF
                                  LIN 1.200E-01
                             52
                                                    10 DIFF
                                  LIN 5.060E+00
 31 9.700E-02 7.223E-03
                             35
                                  LIN 1.280E-01
                                                    30 DIFF
                                  LIN 1.120E-01
                                                     32 DIFF
                             36
                                  LIN 4.000E-01
                                                     27 DIFF
                             49
                                                     35 DIFF
                             53
                                  LIN 1.300E-01
                             61
                                  LIN 1.266E+01
                                                     11 DIFF
 32 6.600E-02 8.126E-03
                                                     31 DIFF
                                  LIN 1.120E-01
                             36
                                                     28 DIFF
                              50
                                  LIN 2.400E-01
                                                     36 DIFF
                              54
                                  LIN 1.800E-01
                                  LIN 7.590E+00
                                                     12 DIFF.
                              62
```

		و بسومها										
33	1.900E-02	6.859E-03	_					- 0	,	34	n i	EE
					LIN					29		
					LIN					13		
			6	3	LIN	200	וטכי	- *U	C)	ĮJ	UX	1 1
34	1.300E-02	6.799E-03	,		4 Y K.I	<i></i>	100	=_^	2	33	n r	FF
		-			LIN					<i>3</i> 5		
		•			LIN					30		
					LIN					14		
			6	54	LIN	Lot	90	E # U	U	7 ~	Uı	4 1
35	3.200E-02	7.225E-03		• •		, ,) (° (^)	r ^	2	34	n i	24
	•				LIN			E-0		36		
		•			LIN			E-0		31		
				_	LIN					15		
			ţ	65	LIN	~ v a 6	220	E ÷ 0	υ.		L/ A	. ,
36	1.900E-02	6.917E-03				~ .	700	c 0	2	35	nτ	EE
			_	39	LIN			E-0		32		
				54	LIN			E-0		16		
			Ć	66 .	LIN	۷٠:	250	E + 0	U	¥ O	Di	
25	1.500E-02	3.191E-03				9 /	200	E_0	1	26	n I	FF
				40	LIN					21		
				43						29		
				47	LIN					5		
					LIN			E + 0		50		
		2 101 5 02	`	95	FIA	، ہ د	2 Z U	L ¥ 0	J	20	بنت	
26	1.200E-02	3.191E-03		40	LIN	1 . :	രമ	F-0	1	25	D I	(FF
					LIN					27		
•					LIN							[FF
				48	LIN							(FF
				4 8	LIN							[FF
				96 .	LIN							RTH
2.2	/ 000E=03	1.076E-02) () .	L 2 1 1	_ 0			•			
21	6.0006-02	. 1.0101 02		41	LIN	7.	100)E-0	2	26	D.	[FF
				42	LIN							ÎFF
		·		45	LIN							IFF
				49	LIN							IFF
	•			69	LIN							IFF
		•			LIN					50	A!	RTH
2.3	1 5006-02	4.625E-03		•								
2.0	Labour or	1002,52		42	LIN	6.	300)E-(2	27	D	IFF
				46	LIN					24	D	IFF
				50	LIN					32	D	IFF
				70	LIN							IFF
				98	LIN							RTH
4.1	2 0305-01	2.651E-03				. .		_				
41	ZaUDVL UI			71	LIN	7 0	500)E+(1	9	D	IFF
				79	LIN					42		
			-1		RAD					100		
40	9.000F-02	2 4.442E-03	-		*	-						
74	. 78 5000 06			77	LIN	1.	880)E + (10	5	D	IFF
				79	LIN					41	D	IFF
		•		21	RAD					100	. 8	UUN

```
43 2.030E-01 2.651E-03
                                 LIN 7.500E+01
                                                   10 DIFF
                             72
                                                   44 DIFF
                                 LIN 1.410E+00
                             80
                                                  100 BOUN
                                 RAD 3.564E-10
                           -122
  44 9.000E-02 4.442E-03
                                                    6 DIFF
                                 LIN 1.880E+01
                             78
                                                   43 DIFF
                                 LIN 1.410E+00
                             80
                                                  100 BOUN
                                 RAD 1.192E-10
                           -123
  45 6.800 E-02 1.8 C8 E-03
                                                   11 DIFF
                                 LIN 3.750E+01
                             73
                                                   100 BOUN
                                 RAD 2.372E-10
                           -124
  45 5.800E-02 1.8C8E-03
                                                   11 DIFF
                                 LIN 3.750E+01
                             74
                                                   100 BOUN
                                  RAD 2.372E-10
                           -125
  47 1.800E-01 1.795E-03
                                                   11 DIFF
                                  LIN 1.000E+02
                              75
                                                   100 BOUN
                                  RAD 6.342E-10
                            -126
  48 1.350E-01 1.795E-03
                                                    12 DIFF
                                  LIN 7.500E+01
                              76
                                  RAD 4.749E-10
                                                   100 BOUN
                            -127
ARTHMETIC NODE PSEUDO-COMPUTE SEQUENCE
                                                    91, COND VALUE IS 3,22000E+0
                               5 THRU LIN CUND
         50 TU DIFF NODE
AODE
                                                    92, COND VALUE IS 3.22000E+0
                               5 THRU LIN CUND
         50 TO DIFF NODE
                                                    93, COND VALUE IS 4.50000E+0
VUUE
                               7 THRU LIN COND
                                                    94, COND VALUE IS 1.80000E+0
         50 TO DIFF NODE
3008
                               8 THRU LIN COND
         50 TO DIFF NODE
                                                    95, COND VALUE IS 3.22000E+0
JUE F
                              25 THRU LIN COND
         50 TO DIFF NUDE
                                                    96.COND VALUE IS 3.22000E+0
N JOH
                              26 THRU LIN COND
                                                     97, COND VALUE IS 4.50000E+0
         50 TO DIFF NODE
i lije
                              27 THRU LIN COND
                                                     98, CUND VALUE IS 1.80000E+0
         50 TO DIFF NODE
36CF
                              28 THRU LIN COND
```

50 TO DIFF NODE

NUUE

B. THERMAL TEST DATA AND INPUT FORMAT FOR NETWORK CORRECTION PROGRAM

The user of the network correction program must be concerned with the test data itself as well as the ultimate use of the test data in the thermal network correction program. Those test measurements obviously in error must be adjusted or eliminated and the format of the translated test data must be compatible with the requirements of the network correction program.

B.1 Thermal Test Data

Both the conventional and the heat pipe platforms were tested simultaneously in a test chamber by mounting the platforms back-to-back as was shown in Figure A-9. Front surfaces of both platforms radiated to a liquid-cooled thermal sink maintained near -50°F.

Temperature measurements were made with 82 copper constantan thermocouples -- 40 on the heat pipe platform and 34 on the conventional platform and 8 on the heat sink plates. Location of these thermocouples on the platforms were indicated previously in Figures A-2 and A-3. Power input to the various heaters was calculated from the measured power supply current and the measured heater resistance.

The platforms were tested under a number of different power settings for both steady state and transient situations. For the present study a transient cool-down condition with no power and a subsequent heat-up condition were selected because of the relatively smooth data points with little perturbations. The sets of test temperatures for the 34-node conventional platform and for the 41-node heat pipe platforms are tabulated in Tables B-l and B-2, respectively, for the cool-down period only. Both the cool-down and the heat-up period temperature data were used for the 10-node model only; this data is tabulated in Table B-3. Note that for the heat pipe platform temperatures of nodes 7 and 27, 8 and 28 were considered to be identical; it should also be noted that the test data used for nodes 7 and 27 represent the average readings of thermocouples 37, 38 and 39 which were essentially identical. Several of the test

Table B-1 Comparison of Test Data and Least Squares Fit. 34-Node Conventional Platform Model, Cool-Down Period

				0 (HR)		-	093 (HR)			255 (HR)		~	42 (HR)			585 (XR)		7	75 (KR)-	
Actual	Thermo-	Danasiation	Test Temp	Least 2nd Order	Squares 4th Order	Test Temp	Least S 2nd Order	quares 4th Order	Test Temp		Squares 4th Order	Test Temp		Squeres 1 4th Order.	Test Temp	2nd Order	Squares : 4th Order :	Test Temp	Least : 2nd Order	Squares 4th Ordo
Mode No.	couple No.	Description									ATURE (°F)									
1	67		86.0	87.8	86.1	84.0	81.8	83.7	70.0	68.8	70.0	55.0	55.7	54.3	41.0	41.8	41.0	28.0	27.3	28.0
Z	69	ĩ	84.0	86.2	84.2	81.0	78.4	80.7	64.0	62.9	64.0	48.0	48.9	47.2	35.0	35.7	35.1	24.0	23.3	24.0
3	71	Ĩ	35.0	36.2	35.1	34.0	32.7	33.8	26.0	25.0	26.0	17.0	17.2	15.5	8.0	9.0	8.0	1.0	.31	.\$8
4	73	Š	10.0	10.5	10.0	9.0	8.1	9.0	5.0	4.4	4.9	0.0	.11	14	-5.0	-4.5	-5.0	-9.0	-9.3	-9.0
5	50	ac g	116.0	118.6	116.2	113.0	110.3	112.7	95.0	93.1	94.9	76.0	76.8	75.2	59.0	60.7	59.1	46.0	44.7	46.0
6	52	ē	229.0	210.3	227.9	148.0	169.9	151.4	96.0	103.5	91.7	73.0	63.1	75.9	56.0	45.3	54.2	42.0	50.0	42.3
7	49	ž	116.0	118.5	116.1	113.0	110.5	112.7	96.0	93.8	95.9	77.0	77.6	76.2	59.0	61.2	59.0	45.0	44.5	46.0
8	51	۰. د	176.0	170.4	176.0	139.0	144.5	139.3	96.0	100.1	95.3	74.0	70.0	73.5	57.0	52.1	56.9	43.0	45.3	43.0
9	53	*	76.0	75.4	75.8	66.0	67.1	66.6	52.0	51.2	51.0	38.0	37.9	38.3	27.0	26.6	26.6	17.0	17.2	17.1
16	54	Şer	23.0	22.9	23.0	19.0	19.2	19.0	. 12.0	11.9	11.9	6.C	5.7	5.8	0.0	.02	02	-5.0	-5.0	-5.0
11	59	ي ا	91.0	93.6	91.0	90.0	87.4	90.0	76.0	73.5	75.5	58.0	59.5	57.6	43.0	44.5	42.9	30.0	28.7	30.0
12	61	g g	107.0	109.3	107.2	102.0	99.1	101.5	80.0	79.1	80.1	61.0	61.6	59.9	45.0	45.7	45.2	32.0	31.0	31.9
13	63	. 1	42.0	43.1	42.0	39.0	38.0	39.1	29.0	27.8	28.6	18.0	18.5	17.8	9.0	9.7	8.9	2.0	1.4	2.
14	55	¥	17.0	17.3	17.1	15.0	14.7	14.8	9.0	9.0	9.2	4.0	3.7	3.6	-2.0	-1.7	-1.9	-7.0	-7.1	-7.
21	68	· 1	89.0	91.2	89.1	88.0	85.5	87.7	74.0	72.5	73.9	58.0	58.9	57.3	43.0	44.1	43.0	29.0	23.1	29.1
22	70	Ĩ	93.0	94.2	93.1	88.0	85.7	87.8	72.0	71.0	71.8	56.0	56.2	55.4	41.0	41.7	41.0	28.0	. 27.4	23.
23	72	ම රිශ්	48.0	49.3	48.1	46.0	44.6	45.9	36.0	34.9	35.9	25.0	25.4	24.6	15.0	15.9	15.0	7.0	\$.3	7.1
24	74	£	15.0	15.4	15.1	14.0	13.5	13.9	9.0	8.9	9.1	4.0	3.9	3.6	-2.0	-1.B	-1.9	-8.0	-8.2	-3.0
25	55	٤	112.0	114.9	112.1	111.0	107.9	110.9	95.0	92.7	\$4.6	76.0	77.5	75.4	€0.0	61.5	60.0	45.0	44.7	45.0
26	56	1 4	158.0	157.2	158.4	136.0	135.7	135.3	95.0	97.7	95.4	72.0	70.4	70.4	\$5.0	52.1	55.4	41.0	42.6	40.9
27	57	o. •	68.0	68.9	67.9	63.0	62.2	63.2	50.0	46.7	49.4	36.0	26.5	35.9	25.0	25.3	24.8	15.0	14.6	15.0
28	58	ž	23.0	23.2	23.0	20.0	20.0	20.1	14.0	13.4	13.7	7.0	6.9	6.9	0.0	.4	1	-6.0	-6.2	-5.9
29	60	7	104.6	106.3	104.0	103.0	100.6	102.9	90.0	87.8	89.7	73.0	74.0	72.5	57.0	53.6	56.9	43.0	41.6	43.0
30	62	.	120.0	122.5	120.3	114.0	110.8	113.5	89.0	88.2	89.1	58.0	68.7	66.8	51.0	51.5	51.2	37.0	23.4	25.9
31	54	Š	59.0	60.6	59.0	56.0	54.3	56.0	43.0	41.5	42.6	29.0	29.9	28.7	18.0	18.8	17.9	9.0	8.3	9.6
32	55	8	20.0	20.8	20.0	19.0	18.2	19.0	13.0	12.3	12.8	6.0	6.5	5.8	0.0	.26	05	-5.0	-6.3	-5.
41	41	- ½-	105.0	107.7	105.2	105.0	102.1	104.6	91.0	0.68	91.0	74.0	74.8	73.1	57.0	59.0	57.1	43.0	41.6	43.6
42	42	Ĭ	109.0	111.7	109.0	103.0	105.4	108.0	94.0	91.2	93.5	75.0	76.3	74.6	58.0	60.0	57.9	44.0	42.5	64.
43	43	ş	189.0	179.3	188.6	138.0	149.1	133.6	94.0	98.3	91.7	71.0	65.4	72.0	54.0	47.8	53.2	41.0	45.5	41.
44	44	<u>\$</u>	235.0	215.9	234.6	149.0	173.1	153.2	96.0	103.0	90.8	71.0	60.8	74.7	54.0	43.0	51.8	41.0	49.3	41.4
45	45	5	101.0	103.0	101.3	94.0	91.2	93.3	69.0	69.0	69.4	51.0	57.3	49.7	37.0	36.9	37.4	26.0	25.0	25.5
45	46	i.	77.0	74.1	76.8	60.0	63.8	60.8	45.0	45.2	43.9	33.0	31.3	33.5	22.0	21.1	21.6	14.0	14.8	14.
47	47	Ŧ	49.0	48.0	49.0	41.0	42.3	41.1	31.0	31.2	30.8	23.C	21.9	22.8	14.0	13.9	13.9	7.0	7.2	7.
48	48	ø	28.0	27.9	28.0	24.0	24.2	24.1	17.0	17.0	16.8	11.0	10.9	. 10.9	6.0	5.6	5.9	1.0	1.2	1.0
100	Saveral	Countery	-50°F									I		1			!		-	

Table B-2. Test Temperatures for 41-Node Heat Pipe Platform

Model Node #	Thermo- couple #	Description	0	.0833	Time Poil .25 Temperate	.417	.583	.75
1	27	<u> </u>	58.	57.	49.	39.	30.	. 22.
2	29		68.	66.	56.	45.	35.	26.
3	31		58.	57.	49.	39.	29.	21.
4	33		60.	59.	51.	42.	33.	24.
5	10		86.	83.	68.	54.	43.	33.
6	12	es	154.	99.	69.	54.	43.	33.
7,27	37	o o Platform Nodes	92.	. 82.	65.	53.	41.	32.
	38	Ę	92.	82.	65.	53.	41.	32.
	39	ıtfo	91.	80.	64.	52.	40.	31.
	{37,38,39}		92.	82.	65.	53.	41.	32.
8,28	40	. 95	89.	79.	64.	51.	40.	30.
9	9	Upper [`] Surface	83.	81.	68.	55.	43.	33.
10	11	تخ	122.	98.	69.	54.	43.	33.
11	. 13	20 C	86.	80.	65.	53.	42.	32.
12	14	5	77.	74.	62.	51.	40.	31.
13	19	·	69.	68.	61.	50.	39.	30.
14	21		89.	83.	65.	52.	40.	31.
15 .	23	<u>J</u>	65.	64.	55.	45.	35.	27.
16	25		52.	51.	47.	<i>A</i> 0.	31.	24.
21	28	4	. 66.	65.	56.	46.	35.	26.
22	30		51.	50.	32.	21.	11.	2.
23	. 32	ν ₇	64.	62.	53.	43.	33.	24.
24	34	Š	61.	60.	53.	44.	34.	26.
25	35	Ē.	92.	8,3.	66.	52.	40.	31.
26	36	Platform Nodes	94.	84.	67.	53.	41.	32.
29	15	<u> </u>	82.	80.	67.	54.	42.	33.
30 -	16		116.	97.	69.	54.	42.	33.
31	17	Surface	85.	79.	65.	52.	41.	32.
32	18		76.	73.	63.	51.	40.	31.
33	20	Lower	73.	72.	65.	53.	42.	32.
34	22	o d	96.	90.	69.	54.	41.	33.
35	24	. [72.	71.	60.	49.	38.	29.
36	- 26		59.	58.	52	44.	34.	26.
41	1	A	82.	79.	68.	54.	43.	33.
42	2		85.	82.	68.	54.	,43.	33.
43	3	des	129.	96.	68.	54.	43.	33.
44	4	Heater Nodes	165.	102.	69.	55.	43.	33.
45	5	e E	81.	78.	63.	50.	39.	30.
46	6	Hea	88.	74.	61.	49.	38.	29.
47	7		81.	74.	61.	49.	38.	29.
48	8		76.	73.	61.	49.	38.	29.
50	Several	Boundary	-50					

Table B-3 Time-Temperature Temperature Data for 10-Node Conventional Platform Model

Nade No.	Thermocouple	Description	0 (hr)	.08333 (hr)	.25 (hr)	1-Down Period .41667 (hr) perature (°F)	.58333 (hr)	.75 (hr)	.8333 (hr)	.91667 (hr)	1,08333 (hr)	Heat-Up P 1.25 (hr) Temperatur	1.50 (hr)	1.75 (hr)	2.0 (hr)
1	Average of t.c.: 67 & 69	4	85.0	82.5	66.0	51.5	38.0	26.0	Å	20.0	28.0	37.0	49.5	58.0	63.5
2	Average of t.c.: 71 &73	e a	. 22.5	21.5	15.5	8.5	1.5	-4.0		-10.0	-7.5	-4.0	0.0	4.0	6.5
3	Average of t.c.: 41,42,49,50 & 59	Platfor ng Heat ides	107.4	105.8	90.4	72.9	55.2	41.8	dh-	32.6	39.0	49.2	63.2	73.6	81.2
4	Average of t.c.: 43,44,51,52 & 61	Upper P ncludin Rod	187.4	135.2	92.4	70.0	53.2	39.8	f Warm	77.4	110.0	126.8	142.0	151.4	157.8
5	Average of t.c.: 45,46,47,48 53,54,63 & 65		51.6	44.8	33.0	23.0	14.1	6.9	Start o	7.38	13.5	19.13	23.9	27.9	32.4
õ	Average of t.c.: 68 3 70		91.0	0.88	73.0	57.0	42.0	28.5	-Dovm;	23.0	30.5	39.5	52.0	61.0	\$7.5
7	Average of t.c.: 72 & 74	E O	31.5	30.0	22.5	14.5	6.5	5	68	-4.5	-2.5	1.0	5.5	10.0	13.5
৪	Average of t.c.: 55 % 60	r Plati Rodes	135.0	123.5	95.0	74.0	57.5	43.5	End of	33.0	37.0	46.0	61.5	72.5	80.0
9	Average of t.c.: 55 & 62	Lower	139.0	125.0	92.0	70.0	53.0	39.0		41.0	63.5	73.5	83.5	103.0	110.0
10	Average of t.c.: 57,58,54 & 66		42.5	39.5	30.0	19.5	10.8	3.0	4	0.0	4.5	9.8	15.0	. 19.0	23.0

B-4

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temperatures for the 34-node conventional platform are plotted in Figure B-l over a time period that includes the transient cool-down and heat-up regions of interest. Heat input to the simulated component (also referred to as heaters in this report) nodes is indicated in Table B-4 for all three math-models; only a single set of heat load values for the 34-node conventional and 41-node heat pipe platform models is shown since the heat input to the two platforms was essentially the same.

B.2 Format for Network Correction Program

Use of the network correction program requires that the test data satisfy two requirements: (1) number of test data points, and (2) program input format.

B.2.1 Number of Test Data Points

The number of test data points should be of sufficient number to reflect, accurately, the time-wise response. A second consideration is that the time-interval between test data points should not be considerably larger than the computational interval of the network solution. The purpose of the former is to eliminate as much as possible interpolation errors, and the latter reflects a requirement of the updating procedure for network correction program which employs the explicit solution routine CNFRDL.

Normally, the number of time-wise data points is not sufficiently numerous as typified by the test data for the platforms and shown in Figure B-l More data points can be obtained by manually curve-fitting the test points and then manually selecting the desired number of data values. Another approach is the curve fitting of the test data by computer means with an appropriate computer subroutine; a least squares approach (SINDA subroutine LSTSQS⁵) was employed for the present study.

The required order of the least squares fit depends upon the smoothness (or lack of) of the test data; thus a trial and error procedure is required to determine the proper order. For the present study, several different polynomial fits in the least squares sense were examined. A

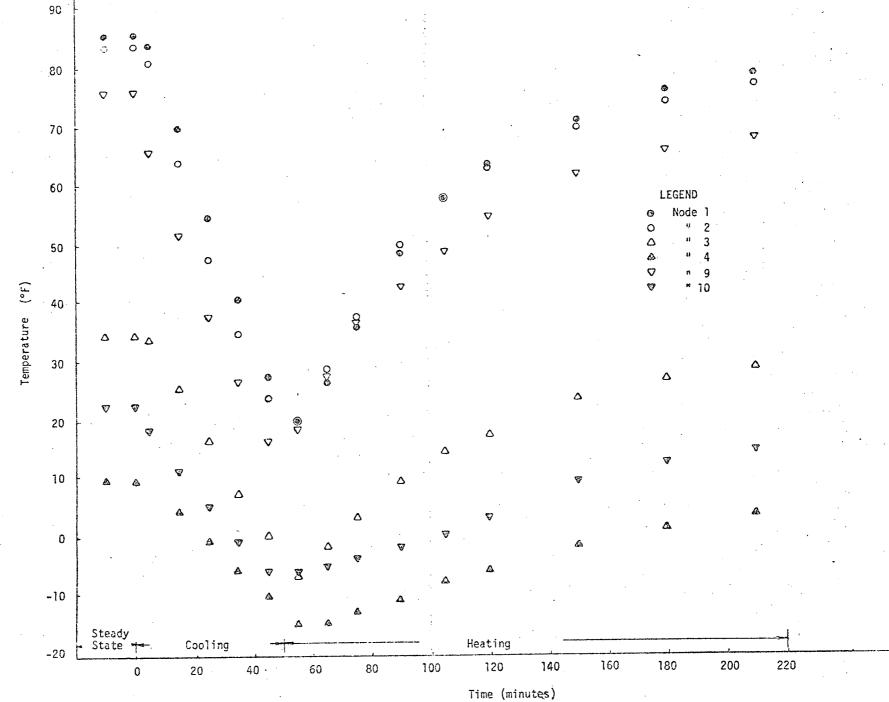


Figure B-1. Typical Transient Temperature Data for 34-Node Conventional Platform

comparison of test data and least squares fit for a second order and fourth order is shown in Table B-l for the conventional platform model. Note that from the six data points representing a particular transient decay, fifty-one interpolated values (in the least squares sense) were generated with an interval between time-slices of .015 hour. The fourth order fit was considered to be satisfactory for the present study. For the 10-node model a time-slice interval of .03 hour was also examined. A major limitation on the use of higher order fit is the presence of undesirable curvature even though the curve-fit is excellent at the test data points.

B.2.2 Test Data Input Format

The thermal network correction program as presently coded requires that the input for the test data be as follows:

- 1. The first set of cards contains the transient time-points to be used with 8 time-points per card. Thus, columns 1 through 10 contain the first time-point, 2 through 20 the second, etc. The format is F10.5.
- 2. The second and subsequent sets of cards contain for each node the temperatures corresponding to the time-points of the first set of cards. The nodal order must be identical to the order of the measured temperature array of the array data block. Thus, if the first node of the measured temperature array were numbered 10, the transient temperature of node 10 would be listed corresponding to the time-points of the first set of cards. Thus, columns 1 through 10 would contain the temperature of node 10 corresponding to the time-point indicated in the first set of cards containing the time-points; columns 10 through 20 would contain the temperature corresponding to the second time-point, and so on. The format is F10.5.

Table B-4. Heat Load on Platform Math-Models

34	-Node & 41	-Node M	lodels			10-No	de Model	
Node #	Steady State	Tra Decay	nsient Heat-up		Node #	Steady State	Tra Decay	nsient Heat-up
Po	wer Dissip	oation (watts)		Poi	wer Dissi	oation (watts)
41	0.	0.	0.	4	3	0.	0.	0.
42	0.	0.	0.		J	0.	0.	· ·
43	24.	0.	24.0	4	4	104.	0.	99.5
44	80.	0.	78.5*	_ţ_	4	104.	0.	99.3
45	0.	0.	0.	<u> </u>		•	e es	- 4
46	7.3	0.	7.9	1	5	21.8	0.	22.1
47	10.7	0.	11.3		ວ	21.0		
48	3.8	0.	2.9					

^{* 75.4} watts for conventional platform 78.5 " heat pipe "

C. COMPARISON OF UNCORRECTED MATH-MODEL AND TEST TEMPERATURES -- CONVENTIONAL AND HEAT PIPE PLATFORMS

It was indicated in Appendix A that both the conventional and the heat pipe platform models were generated using normal math-modeling procedures and no adjustments were made to the conductances to reflect test temperature data. It is thus of special interest to compare analytical temperatures of a math-model with test temperature data. The comparison is tabulated in Table C-1 for the 34-node conventional platform, Table C-2 for the 41-node heat pipe platform, and Table C-3 for the 10-node conventional platform model. Only steady state conditions are presented; refer to Tables A-1, A-2 and A-3 for the heat load to the simulated components.

The results of the comparison show that the difference in temperatures is large, with the analytical temperatures, in general, being higher than the corresponding test temperatures.

Table C-1. Comparison of Steady State Test and Analytical Temperatures of Uncorrected 34-Node Conventional Platform Model

	Temperature (°F)	
$\begin{array}{cc} \text{Node} & & \text{Test} \\ \text{Number} & & \text{T}_{\text{T}} \end{array}$	Analtytical T _A	Difference T _A -T _T
1 86.0 2 84.0 3 35.0 4 10.0 5 116.0 6 229.0 7 116.0 8 176.0 9 76.0 10 23.0 11 91.0 12 107.0 13 42.0 14 17.0 21 89.0 22 93.0 23 48.0 24 15.0 25 112.0 25 112.0 26 158.0 27 68.0 29 104.0 30 120.0 31 59.0 32 20.0 41 105.0 42 109.0 43 189.0 44 236.0 45 101.0 47 49.0 48 28.0	105.0 122.5 36.0 -4.4 131.4 254.8 132.5 203.2 64.0 9.4 124.7 145.7 55.2 9.3 106.0 121.0 37.0 -3.7 135.5 193.4 64.4 9.8 126.7 142.4 56.9 10.5 132.0 130.9 204.6 263.4 64.4 64.1 9.4	19.0 38.5 -1.0 -14.4 15.8 16.5 27.2 12.0 -13.6 33.7 10.2 -7.7 17.0 28.0 -11.0 -18.7 23.4 -3.6 -13.2 22.7 22.4 2.1 -9.5 27.0 21.9 15.6 27.4 -37.3 -12.6 15.1 -18.6

Table C-2. Comparison of Steady State Test and Analytical Temperatures of Uncorrected 41-Node Heat Pipe Platform Model

		Temperature	(°F)
Node Number	Test ^T T	Analytica T _A	Difference $T_A^{-T}T$
1 2 3 4 5 6 7 8 9 10 11 21 3 14 5 16 21 22 3 24 25 26 27 28 29 30 31 32 33 44 45 46 47 48 48 48 48 48 48 48 48 48 48 48 48 48	58. 68. 58. 60. 86. 154. 92. 89. 83. 122. 86. 77. 69. 89. 65. 51. 64. 61. 92. 94. 92. 89. 82. 116. 85. 76. 73. 96. 72. 59. 82. 85. 129. 165. 81. 88. 81. 76.	83.2 58.2 72.2 91.3 47.8 41.0 78.5 77.5 65.0 60.1 114.7 119.6 113.1 106.7 94.8 146.6 84.3 59.6 74.2 93.3 49.3 49.3 93.4 108.9 155.5 181.4 82.8 83.5 83.2	17.8 8.5 5.4 1.5 24.5 15.7 21.1 25.8 10.5 32.5 -2.8 -18.8 3.2 2.3 -17.2 -11.0 12.5 26.5 1.0 9 22.7 25.6 21.1 17.7 12.8 30.6 -16.4 -2.7 -16.7 11.4 23.9 26.5 11.0 12.5 11.0 -1.0 -1.0 -1.0 -1.0 -1.0 -1.0 -1.0

Table C-3. Comparison of Test and Uncorrected 10-Node Model Temperature

Node #		Test Data T _T (°F)	Uncorrected Model T _A (°F)	Difference (T _A -T _T)(°F)
	<u></u>			
1	100	85.0	95.8	10.8
2	form	22.5	10.2	-12.3
3	Upper Platform and Heater Nodes	107.4	148.8	41.4
4	Jer Heal	187.4	200.7	13.3
5	na nd ng	51.6	32.6	-19.0
6	<u> </u>	91.0	98.4	7.4
7	er Platform Nodes	31.5	11.1	-21.4
. 8	olatí ies	135.0	154.6	19.4
9	Lower F	139.0	183.3	44.3
10	^Lo∳	42.5	32.9	-19.6
50	Boundary	50	-	

D. VARIABLES USED IN SUBROUTINES KALFIL AND KALØBS

Use of subroutines KALFIL and KALØBS requires a basic understanding of SINDA. Without this prior experience, use of the two thermal network correction routines would be extremely difficult. In this appendix, the variables used in subroutines KALFIL and KALØBS are described in Tables D-1 and D-2. No attempt was made to provide an overall user's instructions on the two subroutines.

Table D-1. Variables of Subroutine KALFIL

CALLING SEQUENCE:

KALFIL (IPNT, IT(IC), IQ(IC), IC(IC), IG(IC), HT, TP(IC), QB, CB, GB, HSTØP)

IPNT: Intermediate print indicator

- IPNT = 0, no intermediate print; the corrected parameter values are printed after the processing the the <u>last set</u> of temperature data.
- IPNT = +1, intermediate print after the processing of <u>each time-slice</u> set of temperature data; the printout contains various matrices used in KALØBS as well as corrected parameter values. This printout should be used only if the behavior of the KALØBS subroutine is to be examined.
- IPNT = -1, intermediate print after the processing of each time-slice
 set of temperature data; this printout contains corrected
 parameter values and should be used if convergence trend
 of parameter values is desired.
- IT(IC): Array of measured temperatures
 - IT(IC) is an array of actual node numbers of measured temperatures and must be arranged sequentially in the same order as the test temperature input of HT (described below); note that the integer count, (IC), is required.
 - Set IT(IC) = A# (A# is the array number of measured temperatures as used in the array data block.)
- IC(IC): Array soft sources
 - IC(IC) is an array of actual node numbers of soft capacitors

Set IC(IC) = 0 for \underline{no} soft capacitors

IQ(IC): Array of soft sources

IQ(IC) is an array of actual node numbers of soft sources.

Set IC(IC) = A# (A# is the array number of soft sources as used
 in the array data block.)

Set IQ(IC) = 0 for <u>no</u> soft sources.

IG(IC): Array of soft conductors

IG(IC) is an array of actual conductor numbers of soft conductors.

Set IG(IC) = A# (A# is an array of number of soft conductors as used in the array data block.)

Set IG(IC) = 0 for no soft conductors.

HT:

Time-history matrix of test temperatures

Each row of the matrix represents a time-slice of test temperatures with time as the first value in the row, with the remainder being temperatures in the same sequence as used in IT(IC) which was described above.

Set HT = A# (A# is the array number of the time-history temperature data as used in the array data block.)

TP(IC): Array of measured temperature noise and parameter error estimate squared.

TP(IC) contains an array of measured temperature noise and parameter error estimate squared. The order and number of the elements in this array must be as follows:

IT(IC)
IC(IC)
IQ(IC)
IG(IC)

QB, CB, and GB:

Allowable correction range for soft sources, capacitors and conductors, respectively.

- Use of QB, CB and GB allows the user to specify the magnitude of soft source, soft capacitor and soft conductor corrections, respectively. Since allowable corrections greater than 100% can lead to physically unrealistic values, several options are provided.
- Set QB, CB or GB = 0.0 (floating point) if corrections are to be unbounded; this means that corrections may yield negative source, capacitor or conductor values. The unbounded values as output from the processing of a given time-slice set of temperatures are used as input in the processing of the next time-slice set of temperatures.
- Set QB, CB or GB = -N (floating point) for N >1.0. The upper bound is set at $(1.0 + N)Q_0$, $(1.0 + N)C_0$ or $(1.0 + N)G_0$, respectively and the lower bound is set at $(.00001)Q_0$, $(.00001)C_0$ or $(.00001)G_0$; Q_0 , C_0 and G_0 are the original source, capacitor and conductor values. This bounding is performed on the corrected soft parameter output from the processing of a given time-slice set of temperatures and the bounded values are used as input in the processing of the next time-slice set of temperatures.

- Set QB, CB or GB = -N or +N (floating point) for N < 1.0. The upper bound is set at $(1.0 + N)Q_0$, $(1.0 + N)C_0$ or $(1.0 + N)G_0$ and the lower bound is set at $(1.0 N)Q_0$, $(1.0 N)C_0$ or $(1.0 N)G_0$. The bounding of soft parameters is performed after the processing of each time-slice set of temperatures and the bounded values are used as input in the processing of the next time-slice set of temperatures.
- NSTØP: Number of time-slices of temperatures
 - Use of NSTØP allows a user selection on the number of time-slices of temperatures.
 - Set NSTOP = 0 (integer) if all of the temperature data is to be used; the complete temperature data will have M time-slices of temperatures.
 - Set NSTØP = N (Nis an integer < M); this means N time-slices of temperatures of the available M time-slices of temperatures will be processed.

Table D-2. Variables of Subroutine KALØBS

CALLING SEQUENCE:

KALØBS (IPNT, IT(IC), IG(IC), IQ(IC), IG(IC), HT, TNP, QNP, GNP, QB, CB, GB, HSTØP)

IPNT: Intermediate print indicator

- IPNT = 0, no intermediate print; the corrected parameter values are printed after the processing of the <u>last set</u> of temperature data.
- IPNT = +1, intermediate print after the processing of <u>each time-slice</u> set of temperature data; the printout contains various matrices used in KALØBS as well as corrected parameter values. This printout should be used only if the behavior of the KALØBS subroutine is to be examined.
- IPNT = -1, intermediate print after the processing of each time-slice
 set of temperature data; this printout contains corrected
 parameter values and should be used if convergence trend
 of parameter values is desired.
- IT(IC): Array of measured temperatures
 - IT(IC) is an array of actual node numbers of measured temperatures and must be arranged sequentially in the same order as the test temperature input of HT (described below); note that the integer count, (IC), is required.
 - Set IT(IC) = A# (A# is the array number of measured temperatures
 as used in the array data block.)
- IQ(IC): Array soft sources

IQ(IC) is an array of actual node numbers of soft sources.

Set IQ(IC) = 0 for <u>no</u> soft sources.

IC(IC): Array of soft capacitors

IC(IC) is an array of actual node numbers of soft capacitors.

Set IC(IC) = A# (A# is the array number of soft capacitors as used
 in the array data block.)

Set IC(IC) = 0 for <u>no</u> soft capacitors.

IG(IC): Array of soft conductors

IG(IC) is an array of actual conductor numbers of soft conductors.

Set IG(IC) = 0 for <u>no</u> soft conductors.

Table D-2 (continued)

HT: Time-history matrix of test temperatures

Each row of the matrix represents a time-slice of test temperatures with time as the first value in the row, with the remainder being temperatures in the same sequence as used in IT(IC) which was described above.

Set HT = A# (A# is the array number of the time-history temperature data as used in the array data block.)

TNP: Temperature noise estimate

TNP represents the square of the test temperature noise estimate. Experience has shown that a large TNP results in slow responding correction of parameter values. A value of TNP = .005 has been used with some success; this corresponds to a temperature noise of .05°F, which may or may not be a realistic value.

Set $TNP = N^2$ (N is the noise in °F)

QNP: Soft source error estimate

QNP represents the error estimate of soft sources.

Set QNP = N (N is the decimal equivalent of percent error estimate
 of the soft sources.)

CNP: Soft capacitor error estimate

CNP represents the error estimate of soft capacitors.

Set CNP = N (N is the decimal equivalent of percent error estimate
 of the soft capacitors.)

GNP: Soft conductor error estimate

GNP represents the error estimate of soft conductors.

Set GNP = N (N is the decimal equivalent of percent error estimate of the soft conductors.)

QB, CB,

and GB: Allowable correction range for soft sources, capacitors and conductors, respectively

Use of QB, CB and GB allows the user to specify the magnitude of soft source, soft capacitor and soft conductor corrections, respectively. Since allowable corrections greater than 100% can lead to physically unrealistic values, several options are provided.

Set QB, CB, or GB = 0.0 (floating point) if corrections are to be unbounded; this means that corrections may yield negative source, capacitor or conductor values. The unbounded values as output from the processing of a given time-slice set of temperatures are used as input in the processing of the next time-slice set of temperatures.

Table D-2 (continued)

- Set QB, CB or GB = -N (floating point) for N \geq 1.0. The upper bound is set at $(1.0 + N)Q_0$, $(1.0 + N)C_0$ or $(1.0 + N)G_0$, respectively and the lower bound is set at $(.00001)Q_0$, $(.00001)C_0$, or $(.00001)G_0$; Q_0 , Q_0 , Q_0 , and Q_0 are the original source, capacitor and conductor values. This bounding is performed on the corrected soft parameter output from the processing of a given time-slice set of temperatures and the bounded values are used as input in the processing of the next time-slice set of temperatures.
- Set QB, CB or GB = -N or +N (floating point) for N < 1.0. The upper bound is set at $(1.0 + N)Q_0$, $(1.0 + N)C_0$ or $(1.0 + N)G_0$ and the lower bound is set at $(1.0 N)Q_0$, $(1.0 N)C_0$ or $(1.0 N)G_0$. The bounding of soft parameters is performed after the processing of each time-slice set of temperatures and the bounded values are used as input in the processing of the next time-slice set of temperatures.
- NSTØP: Number of time-slices of temperatures
 - Use of NSTØP allows a user selection on the number of time-slices of temperatures.
 - Set NSTOP = 0 (integer) if all of the temperature data is to be used; the complete temperature data will have M time-slices of temperatures.
 - Set NSTOP = N (N is an integer < M); this means N time-slices of temperatures of the available M time-slices of temperatures will be processed.

E. SENSITIVITY COEFFICIENTS OF 10-NODE CONVENTIONAL PLATFORM MODEL

Sensitivity coefficients are used with the thermal correction program to determine the relative sensitivity of each parameter in the network. In general, less sensitive is the parameter less accurate is the correction. Using subroutine STEP, the sensitivity coefficients of the 10-node conventional platform was generated. These results are tabulated in Table E-1.

Table E-1. Sensitivity Coefficients, 10-Node Conventional Platform Model

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	3	8	-5.15605E-02 -1.71172E-03		2	5	4.56217E-C2	7	10	4.51CC9E-02	2 7	-3.26086E-03
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	6	7	-1.50584E-01	1	3	-1.43850E-01	1	2	-1.43137E-01	3	8	-4.804855-02
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VALUE 2.25731E+01

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6 7 7 1.329805-01	í	5	1.28694F-01	3	4	-9.60128E-02	8	9	-6.03319E-02
4 9 5.1830CE-02	6	9	-2.59080E-02	1	4	-2.10333E-C2	3	8 -	-1.245998-02
2 7 -6.38247E-03	ĭ	2	5.73630E-03	5	10	4.99033E-03	1	6	-4.73614E-03
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6	7	-5.61396E-01		1	2	-4.93013E-01	9	10	-4.36231E-01	4	5	-4.32233E-01
4	9	2.01518E-01		<u>.</u>	6	-1.82588E-01		4	1.204925-01	3	8	-5.98234E-02
8	9	5.55352E-02		2	5	4.68491E-02	. 7	10	4:65179E-02	2	. 7	-3.77785E-03
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K L VALUE 6 7 5.31676E-01 4 5 3.86685E-01 6 8 7.77976E-02 3 4 -3.15973E-02 5 10 -6.33159E-03	8 9 -2.251465-02	*** DELTA *** K L VALUE 7 10 4.41872E-01 1 4 1.36898E-01 2 7 -6.47540E-02 3 8 -1.25813E-02	6 9 1 4 9 4	VALUE .23697E-C1 .06412E-C1 .78057E-C3
PARTIAL DERIVATIVES WALUE		*** DELTA *** K L VALUE 4 50 -8.08866E-01	K 1 1 50 -6	<u> </u>
PARTIAL DERIVATIVES K VALUE 4 2.06522E+00	T(7) / Q(K) K VALUE 5 1.56540E+00	*** DELTA *** K VALUE	К	VALUE
PARTIAL DERIVATIVES K VALUE 50 2.36437E+01	T(7) / T(K) K VALUE	*** DELTA *** K VALUE	Κ	VALUE

Table E-1. (Continued)

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6	8	-4.65255E-01	4	9	3.87695E-01	3	8	-3.54687E-01	1	3	-2.89458E-C
6	9	-2.70527E-01	1	4	-2.41791E-01	6	7	-1.81884E-01	1	2	-1.71051E-0
1	6	-2.49261E-02	2	7	-1.83965E-03	5	1.C	-1.76909E-03	.7	10	-1.90774E-0
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4	50	-4.86094E+00	3	50	-4.44845E+00	1	50	-1.48118E+00	5	50	-6.C2361E-0
2	50	-2,03059E-01	<u>-</u> -			-				70	O & C Z D O I E · U
2RTIA	L DER I	VATIVES .									
			T(8) /	O(K)	*** D	ELTA	***		.,	
	K 4	VALUE 1.24111E+01		K 5	VALUE 4.24859E-01	-	K	VALUE		K	VALUE
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	50	VALUE 1.382435+01		K	VALUE		K	VALUE		K	VALUE

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K 4	L VALUE 9 1.08042E+00 9 -6.26539E-01	T(K 9	L 10 4	VALUE -1.07379E+00 -5.43042E-01	*** D:	L 5	VALUE -8.90625E-C1 -4.71425E-01	K 8 6	L 9 8	VALUE -6.66400E-01 -1.97226E-01 -1.14370E-01
6 1 2	7 -1.660475-01 6 -2.38793E-02 7 -2.00457E-03	1 7	2 10	-1.55953E-C1 -8.23299E-03	· 2	3 5	-1.458C9E-01 -7.94019E-03	5 	10	-2.38071E-03
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E-10	VALUE 50 -5.90460E+00	K	50	VALUE -3.31840E+00	K 1	50	VALUE -1.40918E+00	К 5	50	VALUE -7.49474E-01
	_	K	L	VALUE		L			£ 50	
2	50 -5.90460E+00	K	L	VALUE		L			50	

9) / T(K)

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